Geologic Map of the Niagara river


Topography by U. S. Geological Survey
in cooperation with the
N.Y. State Engineer and Surveyor
Geology by Amadeus W. Grabau.

University of the State of New York

# NEW YORK STATE MUSEUM

## 54TH ANNUAL REPORT

OF THE

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## 1900



VOL. 4

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1902

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# CONTENTS

**MUSEUM BULLETINS**

University of the State of New York

# BULLETIN

OF THE

# New York State Museum

FREDERICK J. H. MERRILL *Director*

No. 45 Vol. 9

April 1901

GUIDE TO THE

## GEOLOGY AND PALEONTOLOGY

OF

## NIAGARA FALLS AND VICINITY

BY

AMADEUS W. GRABAU S.D.

*Professor of geology Rensselaer polytechnic institute, and lecturer in geology Tufts college*

WITH A CHAPTER ON

## POST-PLIOCENE FOSSILS OF NIAGARA

BY

ELIZABETH J. LETSON

*Director of the museum, Buffalo society of natural sciences*

ALBANY

UNIVERSITY OF THE STATE OF NEW YORK

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## CONTENTS

# PREFACE

With the support and cooperation of the Buffalo society of natural sciences and the department of paleontology of the state museum, Dr Grabau has prepared this guide to the geology and paleontology of Niagara falls and vicinity with the special purpose of affording to visitors to Buffalo during the season of the Pan-American exposition in 1901 a viaticum in their tours through this region renowned for its scenic features and classic in its geology. The ground has been the subject of a multitude of scientific treatises concerned now with the succession of events in the upbuilding of the rock strata along the canyon of the river; again with the nature of the organic remains inclosed in these strata; sometimes with the changes which the falls have undergone in historic times, but for the most part with the perplexing problems of the origin of the present drainage over the great escarpment and through the gorge, the raison d'être of the falls, the various changes in the course and work of the Niagara river since its birth and the significance of the present topography of the region. These scientific investigations began with the careful surveys instituted by the late Prof. James Hall, state geologist and paleontologist, during the years of his explorations in the 4th geologic district of this state from 1837-43, who, in addition to his record of the work done by this tremendous agent, derived from this region an important term in the New York series of rock formations, the Niagara group, and portrayed the organisms of the various strata which are so superbly exposed along its great channel. Lyell and Bigsby, Logan, Gilbert, Upham, Spencer, Leverett and Taylor are among the names of others who have contributed, from various points of view, facts and hypotheses relating to the geologic history of the river. In no one place however has the general purport of all these various studies been brought together so that the intelligent traveler or student can acquire them in convenient form. It is for this reason that Dr Grabau's work in bringing together in concise form the essence of these investigations, tempered and proved by his own review of them in the field, will not fail to prove serviceable to a large element of the public.

John M. Clarke
*State paleontologist*

Plate 1

Niagara falls from Father Hennepin's view point

## INTRODUCTION —NIAGARA FALLS

AND

## HOW TO SEE THEM[1]

The falls of Niagara have been known to the world for more than 200 years. Who the first white man was that saw the great cataracts is not known, but the first to leave a description was the French missionary, Father Louis Hennepin, who, in company with La Salle, visited the falls in 1678. He was the first white man to use the name, Niagara, for the river and the falls, a name which had been applied by the Neuter Indians, who occupied the territory on both sides of the river prior to the year 1651, when they were conquered by the Senecas, who after that occupied and possessed the territory.[2] In the native language the name is said to signify "the thunder of the waters".

The first sight of the great cataracts must have made a powerful impression on Father Hennepin, unprepared as he was by previous descriptions save those given him by his Indian allies and guides. He speaks of the falls as "a vast and prodigious Cadence of Water which falls down after a surprizing and astonishing manner, insomuch that the Universe does not afford its Parallel".[3] He considered the falls "above Six hundred foot high", and adds that "the Waters which fall from this horrible Precipice, do foam and boyl after the most hideous manner imaginable, making an outrageous Noise, more terrible than that of Thunder, for when the

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[1] Niagara falls are reached from Buffalo by train or electric cars, both of which run at frequent intervals. A direct line of railway runs from Rochester to the falls by way of Lockport. Direct railway connection with western cities is obtained by way of Suspension bridge, while from Toronto and other cities north of Lake Ontario the falls may be reached by train direct, or by boat to Lewiston or Queenston, and thence by train or electric road to Niagara. All electric cars on the New York side run to or past Prospect park, and most of them pass the railway stations. The railway stations are within walking distance of the falls.

[2] Porter, Peter A. Goat island. 16th an. rep't comr's state reservation, 1900.

[3] A new discovery of a vast country in America. 1698. p. 29. Reprinted in part in special report N. Y. state survey for 1879.

Wind blows out of the South, their dismal roaring may be heard more than Fifteen Leagues off."[1]

If today, from our vantage ground of precise knowledge, we smile on the extravagant estimates of Father Hennepin, it may be asked, who among us, that is capable of admiration and enthusiasm at the sight of nature's grand spectacles, would, on coming unprepared on these great cataracts, be able to form a calm and just estimate of hight and breadth and volume of sound?

Since the time of La Salle and Hennepin, the falls have been viewed by a constantly increasing number of visitors. For Americans of the present generation and for people of other lands as well, Niagara has become a sort of Mecca, to which they hope once in their life time to journey. With many this is a hope long deferred in realization, with most perhaps it is a dream never realized, but those who do go and see, come away with their conceptions of nature much enlarged and with memories which cling to the end of life. Fully to appreciate Niagara, one must give it more than a passing glance from the carriage of an impatient driver, who is anxious to have you "do" Niagara in as short time as possible, that he may secure another "fare". Learn to linger at Niagara, and give nature time to impress you with her beauty and her majesty. "Time and close acquaintanceship," says Tyndall, "the gradual interweaving of mind and nature, must powerfully influence any final estimate of the scene". And the growing impression which this incomparable scene produced on him, served to strengthen the desire "to see and know Niagara falls as far as it is possible for them to be seen and known".[2]

It is surprising that many of the visitors to the falls allow themselves to be hurried past some of its most beautiful spots and to bestow on others only casual attention, and then waste a wholly disproportionate amount of time in the museums and curio stores looking for souvenirs purporting to come from Niagara but generally manufactured elsewhere. Real and valuable Niagara souvenirs may be had for the trouble of picking them up, in the minerals, fossils and shells which abound in the vicinity of the falls.

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[1] *Loc. cit.*

[2] Tyndall. Fragments of science, "Niagara".

And, while one gathers these, one's knowledge of Niagara becomes broadened, and the perception grows that there are other lessons to be learned in this region, lessons of even more tremendous import than those taught by the cataracts.

The pedestrian has by far the best opportunity to see and enjoy nature as she is only to be seen and enjoyed at Niagara. The stately forest beauty of Goat island, unequaled in the estimation of those competent to judge, by that of any other wooded spot of similar size; the constantly changing views of gorge and falls and rapids which are obtained from nearly every path on the islands and the mainland on both sides of the river; the magnificence of the turbulent waters as they rush toward you, wave piling on wave, till it seems as if the frail-looking structure on which you stand must inevitably be carried away by them—none can enjoy these to their full extent while sitting in a carriage, though it move never so slowly, or while being compelled to listen to the descriptions and explanations of an unsympathetic and unappreciative driver. If you must ride, patronize the reservation carriages, which leave you wherever you wish to stop and take you on again at your own pleasure.[1]

## Views from the New York side

The first view of the falls which the visitor on the New York side enjoys is generally from Prospect point, or some of the more elevated view points along the brink of the gorge in Prospect park (*see* frontispiece, pl. 1). While impressive, this view by no means reveals to its full extent the matchless grandeur of the cataracts, and in this respect the visitor on the Canadian side has the advantage. However, the views from Prospect point and Father Hennepin's view point should be obtained by every one, and it may be that some will find greater attraction in these than in the more comprehensive views obtained from the other side. While in Prospect park, it is well to descend to the foot of the inclined railway, and get the views

[1]These carriages are run at intervals of 15 minutes, starting from Prospect park, and making the circuit of Goat island. The fare is 15c for the round trip, and stop-overs at all places, and for any length of time on the same day, are allowed.

of the falls from below. The ride on the *Maid of the Mist* will be found an interesting and novel experience, besides affording views of the cataracts obtainable in no other way; but most people will defer this till they have seen more of the cataracts and rapids from above. In visiting the foot of the falls, an umbrella should be taken, while a waterproof cloak will be found of great advantage, for the visitor is apt to be drenched by the spray which will be blown on him unawares. Caution is necessary here, as everywhere at Niagara, to avoid accidents. In the talus heaps of limestone fragments, minerals and occasionally fossils may be found.

From Prospect point the visitor should next turn his attention to Goat island, "the most interesting spot in all America", as Capt. Basil Hall called it. The unpoetic name of this island is, as Mr Porter tells us[1], commemorative of the power of endurance of a male goat, which, in company with a number of other animals, had been left on this island uncared for during the severe winter of 1770-71, and proved the only survivor.

From the bridges which cross to Green, and thence to Goat island, memorable views of the rapids above the falls may be obtained; and the visitor will do well to pause, that he may become impressed by the magnificence of the spectacle. Perhaps he will feel as did Margaret Fuller, who said: "This was the climax of the effect which the falls produced upon me—neither the American nor British fall moved me as did these rapids." The naturalist will be interested to note that, in spite of the fearful rush of water, fresh-water mussels have found a lodging place among the more protected rocks, where they seem to thrive well. Along the shores of the islands, in places where other animals would find it hard to gain a foothold, numerous small gastropods may be found clinging to the slippery rock surfaces.

On Goat island, despite the so-called "improvements" for the convenience of visitors, nature still reigns supreme. The virgin character of the forest is almost undisturbed, as it was when the red man regarded this as the sacred abode of the Great Spirit of

[1]Porter. Goat island.

Plate 2

Luna falls, and the limestone fragments at its base (Copyright by Underwood & Underwood, New York)

Niagara. The botanist will here find a greater variety of plants within a given space than in almost any other district.[1]

But it is in the wonderful views of the falls and the rapids and the gorge which can be obtained from this island, that its chief attraction lies. The various view points are easily found, and the stroller about Goat island would best come on them unawares. Mention may be made of the glimpses of the American falls obtained from the head of the stairway leading to Luna island, as well as from the island itself, and the panorama of rapids, falls and gorge from the Terrapin rocks at the edge of the Horseshoe falls. Every visitor is advised to descend the Biddle stairway and view the falls from below. No charge is made unless one wishes to enter the Cave of the winds, a most thrilling experience for a person of nerve and one unparalleled by any other which may legitimately be obtained at Niagara. But, even if one does not care to go behind the falls, a visit to the foot of the stairway, and a walk along the path at the base of the vertical cliff of limestone will well repay the exertion of the climb. Many noble views of the gorge and the falls may be obtained from the stairway, while from certain points below, impressive sights of the small central fall are to be had. Here too can be seen the undermining action of the spray, which removes the soft shale, leaving the limestone ledges projecting till in the course of time they fall for want of support. On the talus slopes at the foot of the cliff good specimens of minerals and occasional fossils may generally be obtained.

After leaving the Biddle stairway, and the Terrapin rocks, the visitor will proceed southward along the river bank to the bridge leading to the Three Sister islands. On the way the geologist will pause where a wood-road leads off to the left into the famous gravel pit of Goat island, since there the shell-bearing gravels are exposed.[2]

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[1]A catalogue of the flowering and fern-like plants growing without cultivation in the vicinity of the falls of Niagara, by David F. Day, is published in the 14th annual report of the commissioners of the state reservation. In this a total of 909 species are recorded, a large proportion of which are credited to Goat island.

[2]These shells are described in chapter 5.

A small fall known as " The Hermit's cascade " lies between Goat island and the First Sister. In the pool at the foot of this fall Francis Abbot, the Hermit of Niagara, was wont to take his daily bath.

From the bridges and from the islands unsurpassed views of the upper rapids are obtained. These are particularly impressive when seen from the rocks of the Third Sister. Of these rapids as seen from the Terrapin rocks, the Duke of Argyle wrote:

When we stand at any point near the edge of the falls, and look up the course of the stream, the foaming waters of the rapids constitute the sky line. No indication of land is visible—nothing to express the fact that we are looking at a river. The crests of the breakers, the leaping and the rushing of the waters, are still seen against the clouds as they are seen in the ocean, when the ship from which we look is in the trough of the sea. It is impossible to resist the effect of the imagination. It is as if the fountains of the great deep were being broken up, and that a new deluge were coming on the world. The impression is rather increased than diminished by the perspective of the low wooded banks on either shore, running down to a vanishing point and seeming to be lost in the advancing waters. An apparently shoreless sea tumbling toward one is a very grand and a very awful sight. Forgetting, then, what one knows, and giving oneself to what one only sees, I do not know that there is anything in nature more majestic than the view of the rapids above the falls of the Niagara.

On returning to Goat island the visitor may take the reservation carriage for a return to Prospect park, or he may continue his walks around or across Goat island.

In front of Prospect park the electric cars may be taken to cross the river, the bridge-toll which every foot passenger has to pay, being included in the car fare.

### Views from the Canadian side

The Canadian side is reached either by bridge or by the steamer *Maid of the Mist.*[1] Every visitor to the falls should obtain the views from the Canadian side, which are in many respects superior to any obtainable on the New York side. Several rustic arbors have been constructed along the brink of the gorge in Queen Victoria park, and here the visitor may tarry for hours and not weary of

[1] If the visitor plans to take the belt line ride—Niagara, Queenston, Lewiston—he will have opportunity to stop off in Queen Victoria park, and need not make a special crossing.

the sights he beholds. The remarkable vivid green of the water of the Horseshoe falls will excite the observer's interest, and question. Tyndall observes that, while the water of the falls as a whole "bends solidly over and falls in a continuous layer. . . . close to the ledge over which the water rolls, foam is generated, the light falling upon which, and flashing back from it, is sifted in its passage to and fro, and changed from white to emerald-green."[1]

Near the edge of the Horseshoe falls are the remains of Table rock, formerly a projecting limestone shelf of considerable extent, and a favorite view point. Huge portions of this rock have fallen into the gorge at various times, the most extensive falls occurring in 1818 and 1850, with minor ones between and since. On one occasion some forty or fifty persons had barely left the rock before it fell. From the remaining portion of this rocky platform a good near view of the Horseshoe falls is obtained, though the visitor is apt to find himself in a drenching shower of spray at almost all times.

Beyond Table rock, in the upper end of the park, and on the Dufferin islands many attractive walks are to be met with. These are generally little visited and afford an opportunity for solitude and escape from the crowds of sightseers. Some of the best views of the rapids above the falls are to be obtained here. A wooded clay cliff bounds the park on the landward side, generally rising steeply to the upland plateau. Here on July 25, 1814, the memorable battle of Lundy's Lane was fought between the British and the Americans; "within sight of the falls, in the glory of the light of a full moon, the opposing armies engaged in hand-to-hand conflict, from sundown to midnight, when both sides, exhausted by their efforts, withdrew from the field".[2]

At the head of the park, a road leads to the upland, where is situated the famous burning spring. The inflammable gas which here bubbles through the water of the spring is chiefly sulfureted hydrogen, but the quantity is such as to produce a flame of considerable magnitude, and it is asserted that the supply has not diminished for the hundred years or more that the spring has been known to exist.[3]

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[1] *Loc. cit.*

[2] Porter.

[3] An admission fee is charged here.

## The gorge below the falls

The gorge of the Niagara river should be seen from both sides. Here as elsewhere the pedestrian with abundant time has the best opportunity to see the numerous interesting and attractive features; but, since distances here are considerable, it is perhaps more advisable to avail one's self of the conveyances afforded.[1]

The best view of the gorge is afforded by going down the river on the Canadian side and returning by the gorge road. In this way the passenger on the cars gets nearest to the river, particularly if the right hand seats are selected. If the visitor however prefers to go down the river on the gorge road, and return by the Canadian line, let him choose the left side of the cars as nearest to the river in both cases.

After passing Clifton on the Canadian side, and the last of the bridges which here span the gorge, the observer begins to have a view of the whirlpool rapids, which even from this elevation have a threatening aspect. It was through these rapids and through the whirlpool below, that the first *Maid of the Mist* was safely navigated in 1861, having at the time three men on board—a feat which has never been repeated. Through this same stretch of rapids Capt. Webb made his fatal swim, paying for the foolhardy attempt with his life. After passing the rapids we reach the whirlpool, of which good views are afforded from many places along the top of the bank. After crossing several small ravines, that of Bowmans creek is reached. This ravine is a partial reexcavation of the old drift that filled St Davids channel.[2] From the upper end of the bridge which crosses the ravine, a path leads down to the water's edge, the ravine being one of singular attractiveness to the lover of wild woodland scenery. A short distance beyond the bridge is the Whirlpool station of the electric road. Here, from a little shelter built on the extreme point, fine views of the whirlpool and the river above and below it are obtained. The river here makes a right-angled bend, the whirlpool forming the swollen elbow. In the rocky point projecting from the

[1] The visitor will do well to purchase a belt line ticket, which entitles him to make the circuit in either direction and to stop at all important points. The Canadian scenic route will take him along the top of the bank, while the gorge road, on the New York side, takes him close to the edge of the water.

[2] *See* map, and chapter 1.

bank on the New York side the succession of strata is finely shown[1]; and from this point northward the New York bank exposes a nearly continuous section as far as the mouth of the gorge at Lewiston.

A short distance below the whirlpool we reach Foster's flats, or Niagara glen, as it is more appropriately called. This is visited by comparatively few tourists, though it is one of the most attractive spots along the gorge.[2] It marks the site of a former fall, and, besides its interest on that account deserves to be visited for its silvan beauty and its wild and picturesque scenery of frowning cliff, huge moss-covered boulders and dark cool dells, where rare flowers and ferns are among the attractions which delight the naturalist. Many good views of the river and the opposite banks may here be obtained, and the student of geology will find no end to instructive features eloquent of the time when the falling waters were dashed into spray on the boulders among which he now wanders. After leaving Niagara glen the visitor should stop at Queenston hights and obtain the view which is here afforded.[3] If possible the more comprehensive views from the summit of Brock's monument should be obtained.[4]

After descending and crossing to the New York side, one may return directly by the gorge road, leaving the inspection of the fossiliferous strata for another day, or one may, after a rest at the hotel, or on the river bank, spend some hours in studying the sections exposed along the New York Central railroad cut.[5]

The return journey by the gorge road is one of great interest, as it carries the visitor close to the rushing waters of the river. Walking along the roadbed is forbidden, and stops are made only at the regular stations.[6] The first of these is the Devil's hole, a cavern in the rock, of the type described in chapter 3 and supposed to have figured in Indian lore. The ravine of Bloody run, a small stream generally dry during the summer season, was the scene of a fearful massacre of the English soldiers by the Seneca Indians in 1763, the

[1] For a description of these, *see* chapter 3.

[2] *See* chapter 2.

[3] *See* chapter 1.

[4] An admission fee is charged here.

[5] Waggoner's hotel near the Lewiston suspension bridge makes a convenient stopping place, specially if one desires to visit the fossiliferous sections. The Cornell, at the ferry landing, opposite the Lewiston railroad station, is also recommended.

[6] In stopping off, be sure to obtain stop-over checks from the conductor.

whole party with the exception of two, with wagons and horses, being driven over the cliff by the savages, and dashed to pieces on the rocks below. Next above the Devil's hole is Ongiara[1] park, a picturesque wooded slope opposite the southern end of Foster's flats, and like parts of that region are dotted with enormous blocks of limestone, which have fallen from the bank above. A short distance above this we come to the whirlpool, where a stop of some time can profitably be made. But by far the most attractive place at which to stop is the whirlpool rapids. The water which here rushes through a narrow and comparatively shallow channel, makes a descent of nearly 50 feet in the space of less than a mile, and its turbulence and magnificence are indescribable. Seen at night by moonlight, or when illuminated by the light from a strong reflector, the spectacle is beyond portrayal. We may perhaps not inaptly apply Schiller's description of the Charybdis to these waters:

> Und es wallet und siedet und brauset und zischt,
> Wie wenn Wasser mit Feur sich mengt.
> Bis zum Himmel spritzet der dampfende Gischt,
> Und Well' auf Well' sich ohn' Ende drängt,
> Und wie mit des fernen Donner's Getose,
> Entstürzt es brüllend dem finstern Schosse.

## Fossiliferous sections

These sections are to be seen on the cut of the New York Central and Hudson river railroad, Lewiston branch, and along cuts of the Rome, Watertown and Ogdensburg railroad at Lewiston hights. The former are approachable from Lewiston on the north or the Devil's hole station on the south. The approach from Lewiston is the more natural, as it will give the strata in ascending order. Waggoner's hotel makes a convenient starting point. Follow the car tracks southward to where a road leads off on the left. Entering this, a wood-road is found to lead off on the right, which when followed will bring you on the terrace formed by the quartzose sandstone bed, and on which the bridge towers stand. A quarry in the white sandstone by the roadside gives an opportunity to study this rock, which is practically barren of fossils. Beyond this the tracks of the New York Central railroad are reached, which, after traversing a short tunnel hewn out of the Medina sandstone, bring you to the sections in the gorge (plate 12). Care must be exercised in exploring

[1] One of the 40 ways of spelling Niagara.

these sections, as trains are frequent, and rockfalls from the cliffs are among the daily occurrences. With a little caution however the sections may be studied without danger. The total amount of walking necessary from Waggoner's hotel to the Devil's hole is about 3 miles. Near the upper end of the section, where the track enters a rock cutting, a steep path along the river bank leads to the top of the rocky plateau, and a short walk along the top of the bank will bring you to the Devil's hole station. One may also climb the bank in the quarry at the head of the section, and, passing along the top, reach the Devil's hole station by crossing the bridge over the rock-cut before mentioned. At the Devil's hole station[1] one may either take the surface car, which runs to Niagara falls at frequent intervals (5c fare), or, by paying the admission to the Devil's hole, descend to the gorge road and continue the journey to the falls. (A ticket or 50c fare is required here.)

If the sections are approached from the upper end, the Devil's hole station may be reached by the surface electrics[2] or the visitor may leave the cars of the gorge road at the lower Devil's hole station, and, paying the admission fee, ascend the banks by the stairs and paths. The path from the Devil's hole station to the sections leads close along the brink of the gorge. If the sections are visited in the forenoon, the investigator will find himself in the shadow of the cliffs, which is most grateful on a warm summer day.

The sections on the Rome, Watertown and Ogdensburg railroad are reached from Waggoner's hotel by paths leading up " the mountain " one of which begins on the New York Central tracks not far north of the tunnel.

*Geologic nomenclature*

Geologic time is divided into five great divisions, based on the progress of life during the continuance of each. These are:

5 Cenozoic time, or time of " modern life "
4 Mesozoic time, or time of " medieval life "
3 Paleozoic time, or time of " ancient life "
2 Proterozoic time, or time of " first life "
1 Azoic time, or time of " no life "

[1] Refreshments may be obtained here.

[2] These electrics run from near Prospect park to the Devil's hole and return, at short intervals.

Each of these time divisions is farther divided into great eras, those of Paleozoic time being given in the annexed table. Each era is in general divisible into three periods of time, the early, middle, and later, for which the prefixes *paleo* (or *eo*), *meso* and *neo* are used. The farther division of the periods is into epochs.

During the continuance of each great time division of the geologic history of the earth, more or less extensive rock systems were deposited, wherever the conditions were favorable. Thus the Paleozoic rock system is that deposited during Paleozoic time. That part of the Paleozoic rock system which was deposited during the Siluric era, is called the Siluric rock series, and similarly, the name of each of the other great *eras* is also applied to the rock series deposited during its continuance. In like manner each geologic *period* has its corresponding *group* of rocks deposited during its continuance. These rock groups and their farther subdivision into stages have, in New York, received local names, the name of the locality where the rocks are best developed being selected. The rocks formed during Proterozoic and Azoic time are generally spoken of as pre-Cambric.

The following table embodies the result of the latest studies.[1] The thicknesses are chiefly obtained from well records published by Prof. I. P. Bishop. The relations of these strata to each other in this region are shown in the north and south section from Canada to the New York-Pennsylvania line, presented in fig. 1.

Ever since the days of Lyell and Hall the life history of Niagara and the origin of the Great lakes has engaged the attention of geologists the world over. Among the names prominent in connection with studies of the geology of Niagara in one or more of its aspects, may be mentioned those of Bishop, Clarke, Claypole, Davis, Fairchild, Gilbert, Hall, Hitchcock, Lesley, Lyell, Newberry, Pohlman, Ringueberg, Shaler, Spencer, Tarr, Taylor, Upham and Wright, besides a host of others.[2]

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[1] Clarke and Schuchert. Science. n. s. Dec. 15, 1899, 10:3. It will be found to differ in some respects from the table published in the author's Geology of Eighteen Mile creek, etc.

[2] In the field work I have had the efficient assistance of my friend Mr R. F. Morgan of Buffalo.

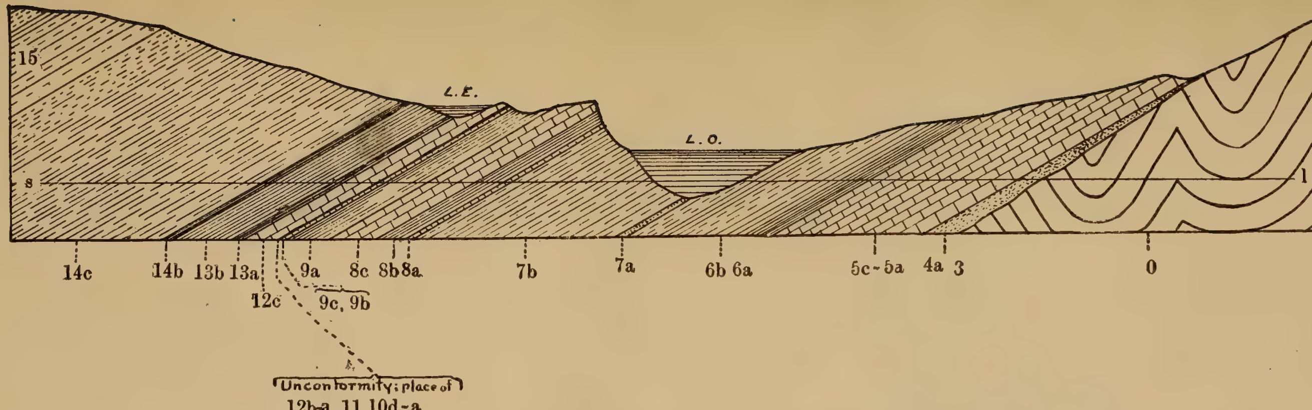


Fig. 1 Section from the Canadian highlands across western New York to the Pennsylvania line, showing the succession of strata. The numbering of the beds corresponds to that of the succeeding table. Owing to the great exaggeration of the vertical over the horizontal scale, the dip of the strata appears much too steep. s. l. = sea-level, L. E. = Lake Erie, L. O. = Lake Ontario. Horizontal scale 1 inch = 38 miles. Vertical scale, 1 inch = 1500 feet.

## Table of Paleozoic subdivisions

| Time scale | Formation scale | New York state rock equivalents | Thickness in the Niagara region |
|---|---|---|---|
| *Paleozoic time* | *Paleozoic system* | | |
| 5 Carbonic era | 5 Carbonic series | | |
| *c* Neocarbonic period | *c* Upper Carbonic group | Absent in New York | |
| *b* Mesocarbonic period | *b* Middle Carbonic group | " | |
| *a* Paleocarbonic period | *a* Lower Carbonic group | " | |
| 4 Devonic era | 4 Devonic series | | |
| *c* Neodevonic period | *c* Upper Devonic group | *c* Upper Devonic group | |
| | | 15 Chautauquan subgroup | ? |
| | | 15a Chemung beds (Catskill sandstone, local facies) | |
| | | 14 Senecan subgroup | |
| | | 14c Portage beds | |
| | | 3) Oneonta beds } local facies | |
| | | 2) Ithaca beds | 938′ to 1541′ |
| | | 1) Naples beds | |
| | | 14b Genesee shale | 17′ to 25′ |
| | | 14a Tully limestone | absent |
| *b* Mesodevonic period | *b* Middle Devonic group | *b* Middle Devonic group | |
| | | 13 Erian subgroup | |
| | | 13b Hamilton beds | 76′ |
| | | 13a Marcellus shale | 211′ |
| | | 12 Ulsterian subgroup | |
| | | 12c Onondaga limestone (including Corniferous) | 108′ to 250′ ? |
| | | 12b Schoharie grit | absent |
| | | 12a Esopus grit | absent |
| *a* Paleodevonic period | *a* Lower Devonic group | *a* Lower Devonic group | |
| | | 11 Oriskanian subgroup | |
| | | 11a Oriskany beds | thin streaks of sandstone |
| | | 10 Helderbergian subgroup | |
| | | 10d Kingston beds (upper shaly) | absent |
| | | 10c Becraft limestone (upper Pentamerus) | absent |

| | | | |
|---|---|---|---|
| | | 10b New Scotland beds (Delthyris shaly) | absent |
| | | 10a Coeymans limestone (Lower Pentamerus) | absent |
| 3 Siluric era | 3 Siluric series | | |
| *c* Neosiluric period | *c* Upper Siluric group | 9 Cayugan group | |
| | | 9c Manlius limestone | 7′ to 8′ |
| | | 9b Rondout waterlime | 60′ |
| | | 9a Salina beds | 386′ |
| *b* Mesosiluric period | *b* Middle Siluric group | 8 Niagaran group | |
| | | 8d Guelph dolomite | absent? |
| | | 8c Lockport limestone (Niagara limestone) | 200′ to 247′ |
| | | 8b Rochester shale (Niagara shale) | 70′ to 80′ |
| | | 8a Clinton beds | 23′ to 40′ |
| *a* Paleosiluric period | *a* Lower Siluric group | 7 Oswegan group | |
| | | 7b Medina sandstone | 1266′± |
| | | 7a Oswego sandstone, Oneida conglomerate or Shawangunk grit | 75′± |
| 2 Ordovicic era | 2 Ordovicic series | | |
| *c* Neordovicic period | *c* Upper Ordovicic group | 6 Cincinnatian group | |
| | | 6c [Richmond beds] absent | ............... |
| | | 6b Lorraine beds } 6a Utica shale } | 630′ |
| *b* Mesordovicic period | *b* Middle Ordovicic group | 5 Mohawkian group | |
| | | 5c Trenton limestone } 5b Black river limestone } | 680′ to 720′ |
| | | 5a Lowville limestone (=Birdseye limestone) | absent? |
| *a* Paleordovicic period | *a* Lower Ordovicic group | 4 Canadian group | |
| | | 4b Chazy limestone | absent? |
| | | 4a Beekmantown limestone (=Calciferous sandstone) } | 10′ to 110′ |
| 1 Cambric era | 1 Cambric series | | |
| *c* Neocambric period | *c* Upper Cambric group | 3 Potsdamian group | |
| | | 3a Potsdam sandstone and limestone } | |
| *b* Mesocambric period | *b* Middle Cambric group | 2 [Acadian] | absent |
| *a* Paleocambric period | *a* Lower Cambric group | 1 Georgian group | absent |
| | | 1a Shales and limestones of Troy and Washington co. N. Y. | |

## *Geologic map*

A few words, descriptive of the accompanying geologic map may be added.

The topography is indicated chiefly by contour lines. These lines are 20 feet apart, and each connects the points which have the same elevation above sealevel. Thus wherever the 300 foot contour line occurs, every point along that line is supposed to be 300 feet above sealevel. The level of Lake Ontario is 247 feet above the sea; therefore the hight of any point above Lake Ontario can be calculated from the contours. Where the contours are close together, the slope of the country is steep; where far apart, it is gentle.

The various color patterns indicate what geologic formations would be shown on the surface of any given area, if the drift covering were removed. The beds of this region all dip gently southward; and, as we proceed northward, the lower beds rise from beneath the covering of the higher. Where steep cliffs occur, as in the gorge of the river or at Lewiston or Queenston, the lower beds crop out beneath the upper ones for only a very short space; hence they appear on the map as narrow color bands only. The character of the outcrops in the buried St Davids channel is only approximately delineated, to the extent indicated by well borings. It is probably much more irregular than is shown.

The outlines of the edges of the various beds from Lewiston eastward are taken from a map by G. K. Gilbert, the man who more than any other is identified with geologic studies at Niagara. The outcrops of the Onondaga and waterlime beds are taken from a map by Prof. I. P. Bishop. For the other outlines the author is responsible.

## *A few statistics*[1]

| | | |
|---|---|---|
| Hight of American falls, Oct. 4, 1842 | 167.7 | feet |
| " Horseshoe falls, " | [2]158.5 | " |
| Mean total recession of American falls between 1842 and 1890 | 30.75 | " |

[1] Chiefly from the annual reports of the commissioners of the state reservation.

[2] The hights vary from 4 to 20 feet with the elevation of the water in the river below the falls.

| | | |
|---|---|---|
| Mean annual recession of American falls between 1842 and 1890 | .64 | feet |
| Mean total recession of Horseshoe falls between 1842 and 1890 | 104.51 | " |
| Mean annual recession of Horseshoe falls between 1842 and 1890 | 2.18 | " |
| Length of crest line of American falls in 1842 | 1080 | " |
| in 1890 | 1060 | " |
| " Horseshoe falls | | |
| in 1842 | 2260 | " |
| in 1890 | 3010 | " |
| Total area of rock surface which has disappeared at the American falls between 1842 and 1890 | 32,900 | sq. ft |
| or | .755 | acres |
| Total area of rock surface which has disappeared at Horseshoe falls between 1842 and 1890 | 275,400 | sq. ft |
| or | 6.32 | acres |

These changes are graphically shown in the successive crest lines of the Horseshoe falls, given in fig. 19, p. 81.

| | | |
|---|---|---|
| Volume of water passing over the falls each minute[1] | 22,440,000 | cu. ft |
| or | 1,402,500,000 | pounds |
| or more than | 7,000,000 | tons |

Depth of water in the channel of Niagara river below the falls[2]: (*see* fig. 18)

| | | |
|---|---|---|
| At foot of Horseshoe falls (center) | 150 to 200 | feet |
| Upper Great gorge, from the falls to the beginning of the Whirlpool rapids (from soundings) | 160 to 190 | " |
| Whirlpool rapids | 35 | " |
| Whirlpool | 150 | " |
| Outlet of whirlpool | 50 | " |
| Opposite Wintergreen flat | 35 | " |
| Below Foster's flats | 70 | " |

[1]Blackwell, Am. jour. sci. 1844, 46 : 67.

[2]Estimated by Gilbert. Am. geol. 1896, 18 : 232-33 and elsewhere.

Width of Niagara gorge[1] (approximate):

| | | |
|---|---|---|
| Opposite the extreme west end of Goat island, and just in front of the Horseshoe falls | 1250 | feet |
| Opposite the center of the American fall | 1700 | " |
| Opposite inclined railway | 1350 | " |
| Between carriage and railroad bridges, narrowest point midway between the two | 1000–1350 | " |
| Just south of railroad bridges | 950 | " |
| Gorge of the whirlpool rapids | 700–750 | " |
| 100 rods south of south side of whirlpool | 1200 | " |
| Same at water line | 850 | " |
| Inlet to whirlpool | 1000 | " |
| Same at water line | 550 | " |
| Outlet of whirlpool | 900 | " |
| Same at water line | 450 | " |
| South of Ongiara park | 1300 | " |
| Just south of Wintergreen flat | 1600 | " |
| River opposite Foster's flats (bottom) | 300 | " |
| Just south of Foster's flats (top) | 1700 | " |
| North of Devil's hole | 1000 | " |
| At the tunnel on the New York Central railroad (plate 12) | 1300 | " |
| Average width below Lewiston | 2000 | " |

[1]Chiefly after Taylor. Bul. geol. soc. Am. 9 : 61-65. Top width is given unless otherwise stated.

Plate 3

The Niagara escarpment above Lewiston (inface of the Niagara cuesta). The lower plain (Ontario lowland) with Lewiston is seen on the left. The sandspit of the Iroquois beach is also shown. R. W. & O. railroad track in the foreground

*Chapter I*

## PHYSICAL GEOGRAPHY OF THE NIAGARA REGION

The physical geography of the Niagara region is of a relatively simple type, its main topographic features being readily interpreted. Unfortunately no very satisfactory birdseye view of the entire

**Fig. 2 Birdseye view of the Niagara region. (After Gilbert) The Niagara escarpment is shown in the foreground, with the lower plain sloping to Lake Ontario. The third upland belt is shown in the distance beyond Lake Erie. The second escarpment immediately north of Lake Erie, is not shown.**

region can be obtained from any of the elevated points of the district; for the chief features are delineated on a scale too vast to be visible from a single vantage point. The best available spot from which a comprehensive view may be obtained is the summit of

Brock's monument, which commands the hights above Queenston, on the Canadian side of the river. Looking northward from this elevation, the observer sees an almost level plain, cut only by the winding lower Niagara, stretching from the foot of a pronounced and often precipitous escarpment to the shores of Lake Ontario, 7 miles away. Ordinarily the distant northern shore of the lake is not readily recognized by the unaided eye, though on clear days a faint streak of land may be seen between sky and water on the distant horizon. A good field glass however will generally disclose the opposite shore, and the much eroded cliffs of Scarborough. Far beyond these, fully a hundred miles to the north of the observer, the crystalline rocks of the Laurentide mountains rise from beneath their covering of Paleozoic strata, as formerly they rose above the waters of the Paleozoic sea. These ancient Canadian highlands, together with the Adirondack mountains of New York, and the old crystalline regions of the Appalachians, constitute the chief visible remnants of the old pre-Cambric North American continent. The erosion of these ancient lands has furnished much of the material from which beds of later date in this region were derived. Some of these beds may be seen in the sections cut by the rivers through the deposits in comparatively recent times, and no more instructive example than the gorge of the Niagara need be cited.

In the banks of the lower Niagara gorge may be seen the cut edges of the red shales and sandstones of the Medina group, the brilliant color of which is in striking contrast with the greenish blue of the water, and the darker green of the foliage which fringes its borders. The plain above is dotted with farms, orchards and hamlets, and is one of the richest agricultural and fruit districts of the country. In the foreground, on opposite banks of the river, lie the sister towns of Queenston and Lewiston, former rival guardians of the head of navigation of the lower Niagara, but now for the second time joined by bands of steel across the intervening gulf. Farther down the stream Niagara-on-the-Lake and Youngstown crown respectively the left and right bank of the river. These four towns of the lower Niagara, hold daily communication by ferry, steamboat or electric railway; the last and the steam railway keep-

ing them in touch with the cities of the upper Niagara and the world at large. This office is also performed by the well appointed steamboats which ply the lower Niagara, and carry passengers across Lake Ontario, to and from Toronto, the capital and metropolis of the province of Ontario. As these steamers enter or leave the Niagara river, they pass Forts Massassauga and Niagara which stand guard on opposite shores at the mouth of the river. The latter fort was established in 1678, and is rich in historic associations, while the Canadian fort is the modern successor of old Fort George, which was destroyed during the war of 1812.

When the observer on the Brock monument turns to the west or to the east, he sees the escarpment on which he stands, and the plain at its foot stretching in either direction beyond his field of view. The continuity of the escarpment is broken at intervals by ravines or gorges which dissect it, the most pronounced of these being the Niagara gorge in the immediate foreground. Westward from Queenston the escarpment is practically continuous for more than 3 miles, when, at the little town of St Davids, it is seen to recede abruptly, and a gap over a mile in width intervenes, beyond which it continues in force, with only minor interruptions, to Hamilton (Ont.), 40 miles west of the Niagara river. The gap at St Davids marks an ancient valley or gorge cut into the upland plateau which terminates at the escarpment. This old valley is traceable southeastward as far as the whirlpool, in the formation of which it has played a prominent part. It is filled throughout its greater extent by sand and clay, into which modern streams have cut gullies of greater or less magnitude.

Beyond St Davids, the escarpment, though indented by numerous streams, is as stated, continuous to Hamilton (Ont.). Here a larger and more pronounced interruption occurs, the escarpment being breached by a broad and deep channel, locally known as the Dundas valley. This ancient channel, with an average width of 2 miles or more, is traceable westward for a number of miles, when it becomes obliterated by drift deposits. Beyond the breach made by the Dundas valley, the escarpment continues in force, its direction however having changed to west of north, or nearly at right angles to its direc-

tion south of Lake Ontario. The eastern face of the Indian peninsula between Georgian bay and Lake Huron and the bold bluff of Cabot's head mark the northward extent of this escarpment, which, after an interruption by a broad transverse channel, is farther traceable in the northern slope of the Manitoulin islands. Eastward the escarpment continues to the vicinity of Lockport, where its continuity is interrupted by two pronounced gulfs, through one of which the Erie canal descends to the lowland of Lake Ontario. Beyond Lockport the escarpment becomes less pronounced; at first it separates into several minor steps or terraces and later it is replaced by a more or less continuous and gentle slope. Beyond the Genesee river it is no longer distinguishable, the surface of the country ascending gently and uniformly from Lake Ontario southward.

Turning now toward the south, the observer sees a second plain extending from the edge of the Niagara escarpment to where its continuity is blended with the horizon. This plain is not as uniform as the Ontario plain, which is fully 200 feet below it, and it is sharply divided by the Niagara gorge, from its northern edge at the escarpment to where, in the distance, a cloud of spray marks the location of the great cataracts. In the walls of the gorge can be seen the cut edges of the strata which enter into the structure of this higher plain, and attentive observation will reveal the fact, that the uppermost of these is a firm-looking limestone bed, which increases perceptibly in thickness toward the north. This thickening of the capping limestone bed, whose upper surface is essentially level, brings out a fact not otherwise readily noticed, namely that the strata all have a gentle inclination or dip to the south. The surface of the upper plain, aside from minor, mainly local irregularities, is essentially level, scarcely rising above the 600 foot contour line. This is the elevation, above the sea, of the base of Brock's monument, and it is the average elevation of the plain in the vicinity of Buffalo, the location of which, 20 miles to the south, is indicated by a perpetual cloud of smoke above the horizon.[1]

[1] A very satisfactory view of the level character of this plain is obtained during a ride by rail from Niagara Falls to Lockport, and thence by train or electric car to Buffalo.

For many miles to the east and west of the Niagara river the plain does not change perceptibly in elevation. Nevertheless, there is a gradual eastward descent, till, on the Genesee river, the surface of the plain, where not modified by superficial deposits, is fully a hundred feet lower than at Niagara. Westward the plain rises gradually, its elevation near Hamilton averaging 500 feet above Lake Ontario, or considerably more than 700 feet above the sea.

Owing to the southward inclination of the strata of this region, the limestone bed which forms the capping rock at the escarpment, eventually passes below the level of the plain, having previously increased in thickness to over 200 feet. The disappearance of the limestone as a surface rock occurs near the northern end of Grand island, as shown by the accompanying geologic map, and from this point southward the surface rock is formed by the soft gypsiferous and salt-bearing shales of the Salina group, which overlie the limestone and in turn pass below the higher strata in Buffalo, where beds of limestone again become the surface rock. Throughout the area where the shales form the surface rock, the plain is deeply excavated on both sides of the Niagara river, a longitudinal east and west valley, now largely filled by surface accumulations of sand and gravel, being revealed by borings. Tonawanda creek occupies this valley on the east, though flowing on drift, considerably above its floor, and Chippewa creek occupies it in part on the west of the Niagara river. This valley, as will be shown later, can be traced westward into Canada and eastward to where it joins the Mohawk valley, with which it forms the great avenue of communication across the state of New York. The northern boundary of the Tonawanda and Chippewa valleys is formed by a limestone cliff similar to, though less pronounced than, the Niagara escarpment. This cliff, generally known as the second limestone terrace of western New York (the Niagara escarpment being the first), is formed by the upper Siluric limestones (Waterlime and Manlius limestone) and the Onondaga limestone of the Devonic series. The latter is a very durable rock and hence it forms a very resistant capping stone. This escarpment is scarcely visible at Black Rock, where it is crossed by the Niagara river, for here it is low, and, in addition, extensive drift

accumulations have obliterated its topographic relief. Eastward and westward however it becomes prominent. A drive along Main street from Buffalo to Akron at the Erie county line will reveal the fact that it gradually increases in hight and boldness, till at the latter place it rises nearly a hundred feet above the Tonawanda valley, which itself is drift filled to a not inconsiderable extent. If we trace this escarpment into eastern New York, we find it progressively increasing in hight, owing to the interpolation, between the Manlius and Onondaga limestones, of the thick beds of the Helderbergian series, which, with the other lower Devonic beds, are entirely absent in the Niagara region, where their place is marked by an unconformity. (*See* figs.1 and 21-24)

If the observer changes his position to some elevated point near Buffalo, he may note that the plain which extends southward from the edge of the second escarpment, presents again a scarcely modified and almost level surface, which south of Buffalo gently descends to a third lowland, that of Buffalo creek and Lake Erie. Like the other lowlands, this one is carved out of soft rocks (Marcellus and Hamilton shales) and has subsequently been filled to some extent by drift deposits. This has been proved by borings which show that the bedrock in the valley of Buffalo creek is 83 feet below the surface of Lake Erie.[1] There are other excellent reasons for believing that the western end of this lowland, now occupied by Lake Erie, was once considerably lower than at present.

On the south the Erie lowland is defined by a range of hills, the northern edge of the great Allegany plateau, which forms the highlands of southern New York and northern Pennsylvania. There are no very pronounced declivities in the northern edge of this plateau in the Lake Erie region, owing no doubt to the relatively uniform character of the rocks composing it, there being no resistant capping bed of sufficient magnitude to produce an escarpment. Farther east, however, owing to the increasing thickness of the beds and their more resistant character, a prominent escarpment is developed, which near the Hudson unites with the escarpment of the lower series, and with it constitutes the prominent Hel-

[1] Pohlman. Life history of Niagara. 1888. p. 4.

derberg range, which culminates in southeastern New York in the high plateau of the Catskills. The Allegany plateau is everywhere much dissected by streams whose gorges have made the scenery of southern New York famous.

We have now seen that the topographic features of the Niagara district are arranged in a series of six east and west extending belts of alternating lowlands and terraciform elevations. The lowlands are the Ontario, Tonawanda-Chippewa, and Erie, the uplands are defined by the Niagara escarpment, the Onondaga escarpment and the hills of southern New York which constitute the northern edge of the Allegany plateau. The northern boundary of this belted country is formed by the old Canadian highlands.

We must now briefly consider the various strata of which the area under consideration is constructed, their origin, and the manner in which the topographic features of this region were produced. A brief review of the table of Paleozoic strata, given on pages 20 and 21, will be helpful to an understanding of the succeeding pages.

### Development of the Paleozoic coastal plain

The Laurentian old-land is composed of rocks older than the Cambric period of the earth's history. These are largely of igneous origin, and such as were originally sediments have generally suffered much alteration through heat, pressure and other causes, and in most cases have assumed a more or less crystalline character. Though many of these pre-Cambric rocks may show apparent stratification, the present attitude of the beds does not often bear a close relation to their original condition. Indeed, these ancient rocks are generally much disturbed, their beds folded and flexed, and their laminae much contorted. Nor do the layers of the pre-Cambric rocks bear any normal relation to those of later date, the two series being wholly discordant with each other. The older beds are much worn, vast portions of the ancient folds having been swept away by erosion, and on the truncated edges of the remaining portions the newer strata were deposited in an essentially horizontal position. This *unconformity* of relation between the newer and older strata is a marked feature wherever the two series are ex-

hibited in contact with each other. Generally the older rocks have been worn down to an undulating plain (or peneplain), and the succeeding beds made from the fragments which were worn from the old land.

In the area under consideration, the ancient erosion surface of pre-Cambric rocks was overspread by a deposit of sand and occasionally gravel, which commonly possesses characteristics pointing to a very local origin. Thus the pebbles found in the lowest layers of the covering sands, i. e. the Potsdam sandstone, are sometimes of the same lithic character as the crystalline rocks near by. The Potsdam sandstone is a shallow-water rock, and during its accumulation a progressive subsidence of the sea floor took place, thus allowing the deposition of beds of considerable thickness. This subsidence brought with it a northward migration of the shore line of the sea, so that the region of the former coast line gradually became more remote from the shore. As a consequence, land-derived material became less abundant in this off-shore district, being deposited mainly along the new coast line, while farther out to sea calcareous deposits, resulting in part from the shells of organisms, became relatively more abundant. A profile through the strata of this region, such as would be obtained in a well or shaft sunk to the crystalline floor, would show a progressive decrease in the land-derived, or terrigenous material from the Potsdam sandstone upward to the top of the Trenton limestone, and a correspondingly progressive increase in the amount of calcareous matter. This indicates a sustained subsidence of the sea floor, and hence a migration of the shore with its attendant terrigenous deposit. It will also be seen that the lithic character of any particular formation is not the same throughout its extent, but that the local characteristics, or *facies*, show considerable variation. Close to the shore each formation would present a terrigenous character, i. e. would show gravelly, sandy or clayey facies, while away from shore each formation would pass into its calcareous facies, which would increase in purity with the increase in distance from the source of supply of terrigenous sediment. Thus the Potsdam formation has calcareous as well as sandy facies, with facies of intermediate type connecting them.

The Utica shales and the arenaceous Lorraine shales which follow on the Trenton limestones show a return of land-derived deposits due probably to a shoaling of the water. This may have been caused by an upward movement of the sea bottom or by a partial withdrawal of the water into deepening oceanic basins. Some abrupt change is indicated by the sudden transition from limestone to black shale. Another abrupt change occurred at the close of the Ordovicic era, as indicated by the marked contrast between the Lorraine shales and the Oneida and Medina beds which immediately succeed them.

The Siluric deposits of this region began as shallow water accumulations, the lowest bed being the Oswego sandstone, which farther east, is replaced by the conglomerates of Oneida county and the Shawangunk range. The marls and shales of the Medina series succeed these sandstones with an aggregate thickness exceeding 1100 feet. A heavy stratum of gray quartzose sandstone, varying in thickness up to 25 or 30 feet, separates, in the Niagara region, the lower from the upper Medina shales and sandstones, which have an approximate thickness of 100 feet. The Clinton shales and heavy limestones follow on the Medina, with a thickness averaging 30 feet. The Rochester shales, with a thickness of 60 to 70 feet, follow the Clinton limestones and are in turn succeeded by the Lockport limestone, whose average thickness, obtained from well records, approximates 250 feet in this region. The Salina shales succeeding the Niagara beds (Rochester shales and Lockport limestone) have an aggregate thickness of less than 400 feet, and are followed by the Waterlime and the Manlius limestone, the former averaging 50 feet in thickness, the latter from 7 to 8 feet. The lowest Devonic beds are absent in this region, the Onondaga limestone resting directly on the Manlius beds, there being, as before noted, an important though not very pronounced unconformity between the two. A glance at the geologic map of this region will reveal the fact that the lower strata rise from under the covering newer beds on the north, and occupy a belt of country of greater or less width according to the thickness of the beds. Where they come to an end, the next lower beds make their appearance. The discontinuation of the higher

beds northward is due to a thinning out of the exposed portion of the strata, as can be readily seen in the Lockport limestone bed, which is less than 30 feet thick at Lewiston, but more than 80 feet at the falls, increasing in thickness southward to 250 feet or more. Where, however, the strata are not exposed on the surface, i. e. where they are only shown in sections under cover of the overlying rock, no such thinning is seen. This may be observed in the case of the Clinton beds and the upper Medina sandstones. In some cases these beds are seen to even thin southward, as proved by borings. The thinning of these strata does not, as is often assumed, mark the original thinning of the beds toward the shore on the north, but is evidently due to erosion. A brief résumé of the origin of the various strata will make this clear.

The Medina sandstone is an ancient shore and shallow water deposit, as will be more fully pointed out in chapter 3. The sands and gravels, which with some finer muds, make up this rock, are all derived from some preexisting land. The only source of supply was the old Laurentian land on the north and the Appalachian old-land on the south. It is true that, owing to the elevation at the beginning of Siluric time, some of the pre-Siluric stratified rocks may have been raised above the sealevel and added to the old-land, and that part of the Medina sands may have been derived from these. Even then the largest amount of detritus was probably derived from the crystalline old-lands, the progressive accumulation of 1200 feet of Medina rock marking a corresponding subsidence and a concomitant encroachment of the seashore of the Medina sea on the old-land. Thus the Medina deposits gradually overlapped the Ordovicic and Cambric deposits and probably eventually came to rest entirely on the crystalline pre-Cambric rocks. Continued subsidence, at least in the Niagara region, produced the purification of the water, so that eventually the limestones of the Clinton epoch could be formed in a region remote from that in which terrigenous material was accumulating. This was likewise true of the Lockport limestone, which was deposited after an interval, during which the calcareous shales separating the two limestone series accumulated. While

these deposits, particularly the limestones, point to a considerable distance from the shore line, we are by no means at liberty to assume that no shore formations accumulated during this period. In fact, it would be difficult to understand the non-accumulation of terrigenous material along the shores of any land during any period of the earth's history unless such land was without even moderate relief. As will be shown in chapter 3 there are reasons for supposing that a considerable land barrier existed in the north as well as the east and southeast, and thus we may assume that shore deposits of terrigenous material were formed while the limestones were accumulating in the clearer waters. That the shores of this period did not consist of Medina sandstone is indicated by the absence of any such material in the shales of either the Clinton or Niagara series. It is highly probable that the shore was still formed by the old crystalline highlands, and that the accumulating Clinton and Niagara sediments overlapped and completely buried the Medina beds. The limestones are chiefly fragmental in origin, being composed of calcareous and magnesian sands. These, as will be shown later, were largely derived from the destruction of coral reefs and shells growing in the immediate neighborhood. They indicate shallow water, a conclusion emphasized by the occurrence of well marked cross-bedding structure in some of the beds of limestone. We may assume a gradual passage from pure calcareous beds to beds consisting more and more of terrigenous detritus as we approach the old shore line, where quartz sands probably constituted the chief material of the deposits.

We may obtain an approximate indication of the former extent of these strata if an attempt be made to restore the portions which must have been removed by erosion. We may consider the Clinton and Niagara as a unit, assuming that near the old shore their beds were practicably indistinguishable. The average dip of the strata of this region is 25 feet to the mile (a moderate estimate, as the dip ranges up to 40 feet), and the base of the Clinton-Niagara is approximately 400 feet above sea level. Continuing this dip northward for a hundred miles to where the present borders of the oldland are exposed, the base of this group would have risen 2900 feet

above the sea, an elevation sufficient to overtop the highest peak of the present Laurentides; for, according to Logan, "in the country between the Ottawa and Lake Huron the highest summits do not appear to exceed 1500 or 1700 feet, though one . . . probably attains 2300 feet".[1] We assume of course with good reason that the Laurentides at that period were much higher than now, for they must have suffered enormous erosion during the long interval since the close of Siluric time.[2]

Since the deposition of these Siluric strata the region under consideration has suffered an enormous amount of denudation, having been brought to the condition of a low nearly level tract or *peneplain*, but little above sea level, not once, but probably a number of times, separated by periods of elevation and at least one of sub-

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[1]Logan. Geol. Canada. 1863. p. 5.

[2]The Niagara beds of Lake Temiscaming, in the great pre-Cambric area of Canada and 150 miles distant from the nearest beds of the same age, are of interest in this connection. They occupy an area about 300 miles due north of Lewiston and on the north side of the present Laurentide chain. According to Logan they do not properly belong to the former extension of the Niagara beds of the region under consideration, but rather to the Hudson bay area on the north. They are of interest however as showing the great former extent of these formations. They lie unconformably on the pre-Cambric rocks, and the basal members are generally sandstones and often conglomerates "containing large pebbles, fragments, and frequently huge boulders of the subjacent rock" (Logan, p. 335). The thickness of the formation here is estimated at between 300 and 500 feet. The Ordovicic and Cambric strata are absent, showing a progressive encroachment of the sea on the old-land, and a consequent overlapping of the strata. Outliers of earlier strata are found in more southern portions of Canada, resting on the pre-Cambric surface, and many of these indicate a progressive overlapping of later over earlier beds. Lawson holds that this indicates, that most of the Canadian old-land was covered by the early Paleozoic strata, and that erosion since Paleozoic time has resulted in simply removing these overlying rocks. (Bul. geol. soc. Am. 1 : 169 et seq.) He holds that comparatively little erosion of the old-land has occurred since Paleozoic time, the present surface being essentially pre-Cambric and only revealed by stripping of the overlying rocks. It is not improbable however that some of these distant outliers may have been preserved during the extensive denudation of the old-land, by having been faulted down previously in a manner well known to have occurred in the Scandinavian old-lands, a solution suggested to me by my friend, A. W. G. Wilson, of Harvard university.

sidence. The present surface of the Niagara plateau is therefore not to be considered as identical with the old surface of deposition, but as due to prolonged peneplanation, or erosion to near sealevel, completed probably toward the close of Mesozoic or the beginning of Cenozoic time. The following diagram (fig. 3) will illustrate the relation between the strata and the surface of the land at 1) the close of Siluric time, 2) late Mesozoic or early Cenozoic time, after the completion of the last cycle of erosion and the reduction of the land to peneplain condition, and 3) the present surface.

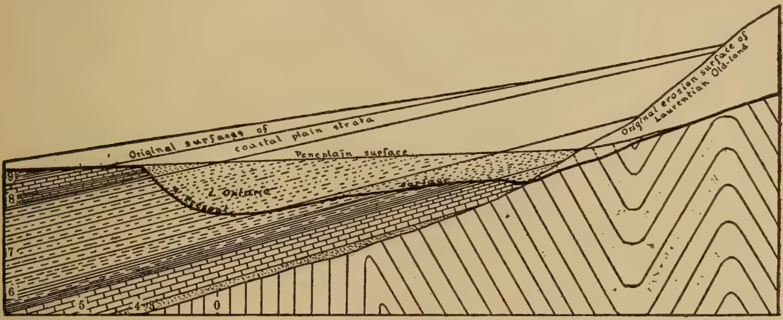


**Fig. 3** Diagram of ancient Paleozoic coastal plain, and its relation to the Mesozoic peneplain surface and the present land surface. The numbering of the beds corresponds to that of the table.

Between the close of the Siluric and beginning of Mesozoic time a long period intervened, during which this region was at first a land surface, suffering considerable erosion, but later was resubmerged, and covered with extensive deposits of Devonic limestones, shales and sandstones. The final emergence took place at the close of Paleozoic time, the succeeding Mesozoic time being in this region probably an uninterrupted period of erosion, during which the land suffered the combined attacks of the atmosphere and of running water.

### Development of the drainage features.

The water which falls as rain or snow on the land either evaporates, runs off on the surface, or sinks into the ground, where it constitutes the ground water. That which evaporates, accomplishes little or no direct geologic work, but both the surface and underground waters are important geologic agents. If the surface on which the water falls is a perfectly smooth but inclined plain, the water will run off in the form of a thin sheet. A perfectly smooth

land surface is however unknown, and the run-off of the surface waters is always concentrated along certain lowest lines, thus constituting brooks, streams and rivers. While there may be numerous drainage lines of this type, they generally unite into a few master streams, the direction of whose flow is down the inclination of the surface of the land. Such streams are known as *consequent* streams, their direction of flow being consequent on the original slope of the surface.

When the strata of the Niagara region became a part of the dry land, from the relative lowering of the water level (which may have been due to rise of the land or to drawing off of water by the deepening of the oceanic basins), they formed a broad, essentially monotonous belt of country fringing the old-land on the north, i. e. a marginal coastal plain. The strata of this plain had a gentle southward inclination, a feature shared by the surface of the plain. Consequent streams quickly made their appearance on this plain, a number of them probably coming into existence almost simultaneously and running essentially parallel from the old-land, across the new coastal plain into the sea. These streams soon cut down into the coastal plain, carving channels for themselves and thus establishing definite lines of drainage. As the streams at first consisted entirely of the run-off of the moisture which fell on the plain and in the higher old-land portion, it is evident that, unless the rainfall was continuous, or unless extensive snow fields were present to supply water, these young streams must have fluctuated greatly in volume of water, and at intervals become entirely dry. This condition continued till the valleys, cut by these streams of run-off water, had become sufficiently deep to reach the level of the underground water, when the supply, augmented by springs, became much more constant. Thus in course of time large valleys, supplied with large rivers, came into existence. Meanwhile the sides of the river valleys were attacked by the atmosphere, and degradation of the cliffs cut by the stream resulted.

As long as a river is narrow and vigorously undercuts its banks, the latter will be steep, and the river channel will have the character of a gorge. This generally continues as long as the river is cutting

Plate 4

American and Luna falls from below, with limestone fragments fallen from the cliff above (Copyright by Underwood & Underwood, New York)

downward, i. e. till the grade of the river bottom is a very gentle one, when lateral swinging widens the gorge by undercutting the banks, and atmospheric degradation quickly destroys the steep cliffs which the river does not keep perpendicular.

During the process of drainage development, numerous side streams come into existence, which join the main stream as branches. These begin as gullies formed by the rainwater running over the sides of the banks into the main stream. A slight depression in the surface, or a difference in the character of the material composing the banks, may determine the location of such a gully, but, once determined, it will become the cause of its own farther growth. For the existence of this gully will determine the direction of flow of succeeding surface waters, and so in the course of time the gully will become longer and longer by headward gnawing, till finally a channel of considerable magnitude is produced. Streams of this type are known as *subsequent* streams, and they very generally have a direction varying from a moderately acute to nearly a right angle with reference to the main or consequent stream.

As the dissection of the Niagara coastal plain continued, the higher portions of the strata, i. e. those nearer the old-land, were slowly removed, and the beds lying beneath these were thus exposed. The latter strata were generally of a more destructible character than the overlying ones, and on this account great lowlands, parallel to the old shore line, or the line of strike of the strata, were worn in them by subsequent streams. The more resistant beds, meanwhile, favored the formation of more or less prominent cliffs or escarpments which faced the lowlands, and being undermined slowly retreated southward, thus increasing the width of the lowlands. These features are today repeated in the Niagara escarpment which faces the Ontario and Georgian bay lowlands, and the escarpments formed by the outcrops of the Ordovicic limestones farther north. The diagram, fig. 4, illustrates the probable condition during early Mesozoic time. The great master consequent streams indicated are: the Saginaw, the Dundas and the Genesee, flowing from the old-land on the northeast, southward or southwest-

ward into the Mesozoic interior sea. There were probably other consequent rivers, whose location may be in part indicated by some of the valleys now occupied by the Finger lakes of New York. Subsequent streams, flowing along the strike of the beds and capable of accomplishing much erosion by undermining the resistant capping beds of the escarpments, continued to widen the longitudinal (i. e. eastwest) lowland areas, while the transverse valleys of the consequent streams remained relatively narrow.

The topographic relief feature produced by this normal development of drainage on a young coastal plain consisting of alternating harder and softer strata, has been named a "cuesta",[1] and may be briefly defined as an upland belt of slightly inclined coastal plain strata, with a surface gently sloping toward the newer shore, and a steep escarpment, or *inface,* fronting a low belt, or *inner lowland,* which separates the cuesta from the old-land upon which its strata formerly lapped. The existence of the cuesta form is usually due to a more or less resistant stratum overlying a less resistant one, as, for example, the limestones overlying the upper Medina shales. The inface of the cuesta is continually pushed back by the undermining subsequent streams, aided by atmospheric attack, and thus the belt of low country, lying between the cuesta and the old-land, is continually widened, while during the same time the valley of the transverse consequent stream which carries out the drainage increases comparatively little in width. It must be remembered however that the lowland can never be deepened below the depth of the valley of the consequent stream which carries its waters through the breach in the cuesta.

While the main drainage of this region was undoubtedly southwestward by consequent streams, which flowed through the cuesta in gorges, and by subsequent streams flowing into the former, and occupying the inner lowlands, short streams, flowing toward the old-land, down the inface of the cuesta, were probably not uncommon. These streams began to gnaw gullies back from the inface

[1] Davis, W. M. Science. 1897. New series. 5:362; *also* Textbook of physical geography. 1899. p. 133. Pronounced kwesta, a word of Spanish origin "used in New Mexico for low ridges of steep descent on one side and gentle slope on the other".

of the cuesta, and ultimately prolonged these gullies into gorges, and carried the drainage into the subsequent streams. Streams of this type, which have their representatives in all coastal plain regions, have been called *obsequent* streams,[1] their direction of flow being opposite to that of the consequent streams. The following diagram (fig. 4) illustrates this type of a stream and its relation to the subsequent and consequent streams. To this type of stream belongs the ancient St Davids gorge, as will be shown more fully in subsequent pages.

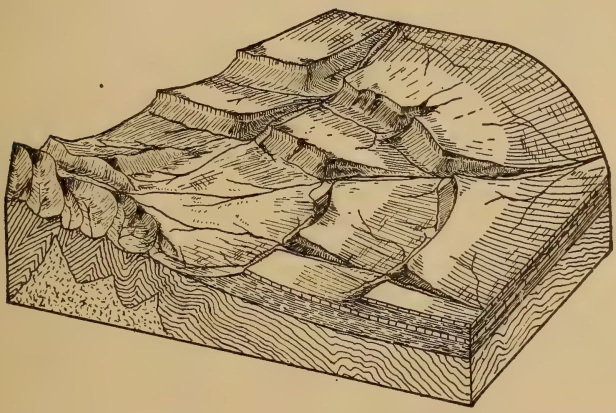

**Fig. 4 Diagram of a portion of a dissected coastal plain, showing old-land on the left, and two cuestas with their accompanying inner lowlands. Three consequent streams have breached the cuestas, and subsequent streams from the lowlands join them. An obsequent stream is shown in the center of the outer cuesta.**

If we assume that during the greater part of the Mesozoic era, the land in this region remained in a constant relation to the sealevel, it becomes apparent that the southward retreating infaces of the cuestas formed by the resistant members of the Paleozoic rocks, became lower and lower, as the southward inclination of the strata carried the resistant beds nearer and nearer to sealevel. Eventually the escarpment character of the infaces must have become obsolete, from the disappearance, beneath the erosion level, of the weaker lower strata, which permitted the undermining of the capping beds. When this occurred, the capping strata alone continued exposed to the action of the atmosphere, and, from a cliff character, their exposed ends were planed off to a wedge shape, thin-

[1]W. M. Davis

ning northward at a rate proportional to the dip of the beds. The ultimate result of all this erosion was the reduction of the land to a low peneplain, which did not rise much above the sealevel. Portions of this peneplain are today preserved in a scarcely altered condition, in the Niagara upland, the region about Buffalo and other localities. The slight change which these regions have subsequently undergone leads to the supposition that the peneplain was completed in comparatively recent geologic time, possibly at the beginning of the Tertiary era, or even more recently. This is also shown by the comparative narrowness of the valleys cut into the peneplain surface in preglacial times. The present altitude of this peneplain in the vicinity of the Niagara river is approximately 600 feet above sealevel, while southward it rises. There is however good presumptive evidence, some of which will be detailed later, that, during a period preceding the glacial epoch, the land in the north stood much higher than at present, so that the slope of the surface was southward. An accentuation of slope would cause a rejuvenation of the consequent streams, which, in the later stages of peneplanation, had practically ceased their work of erosion on account of the low gradient of the land. As a result of the renewal of erosive activity the early Mesozoic topography was in a large measure restored, but the inface of the Niagara cuesta, the top of which is now found in the Niagara escarpment, occupied in the restored topography a position considerably farther to the south than that characteristic of early Mesozoic time.

We may now examine more in detail the channels of the consequent streams which dissected this ancient coastal plain, and the extent of the inner lowlands drained by the subsequent streams tributary to them.

**Dundas valley.** The Dundas valley appears to have been the outlet for the master consequent stream of this region, the Dundas river. This valley, as before noted, breaches the escarpment at Hamilton (Ont.), near the extreme western end of Lake Ontario. The valley has been carefully described by Spencer, who considered it the pathway of the preglacial outlet of Lake Erie into Lake Ontario, the drainage of the Erie valley being in his opinion by a

river which followed the present course of the Grand river, above Cayuga, past Seneca and Ancaster into the western end of the Ontario valley. It is extremely doubtful that such a stream ever existed, certainly it is highly improbable that the Dundas valley owes its existence to any stream which flowed eastward or toward the old-land, for it is altogether too broad, and continues too uniformly to permit its being regarded as the valley of an obsequent stream. Moreover, its peculiar position at the elbow of the escarpment is most suggestive of a consequent origin, for we would expect the face of the cuesta to make a reentrant where the master stream gathers its converging tributaries and flows out through a great breach in the cuesta.

The Dundas valley is 5 miles wide at Hamilton but rapidly decreases in width to 2 or 2½ miles at the top, where the limestone forms decidedly sharp summit angles (Spencer). Its northern wall has been traced westward for 6 miles to Copetown, and its southern for 3½ miles to Ancaster. Beyond these points the valley is filled with drift which has been much dissected by modern streams. The axis of the gorge is about n 70° e, and the glacial scratches observed on the rock surfaces at its summit, with few exceptions, make angles of 30° or more with it (Spencer).

At Hamilton the bedrock was found to be absent to a depth of 227 feet below the surface of Lake Ontario. The well from which this record was obtained is about 1 mile distant from the southern side of the Dundas valley, which is here 5 miles wide. The total known depth of the canyon is, according to Spencer, 743 feet, but he calculates that it reaches 1000 feet near the center.[1] Along the northern shore of Lake Erie well records have shown the absence of drift to a considerable depth. Thus, according to Spencer, at Vienna, 100 miles due west of Buffalo, the drift is absent to a depth of 200 feet below the surface of Lake Erie, while at Port Stanley, 20 miles farther west, it is absent to a depth of 150 feet below the lake. At Detroit the drift is 130 feet deep. At St Marys on the northwest and Tilsonburg on the southeast of a line connecting

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[1] Spencer. Pa. geol. sur. Q 4. p. 384–85.

Port Stanley with Dundas, Devonic limestones occur at a considerable elevation above Lake Erie (Spencer). Hence the southwestward continuation of the Dundas channel must be placed between

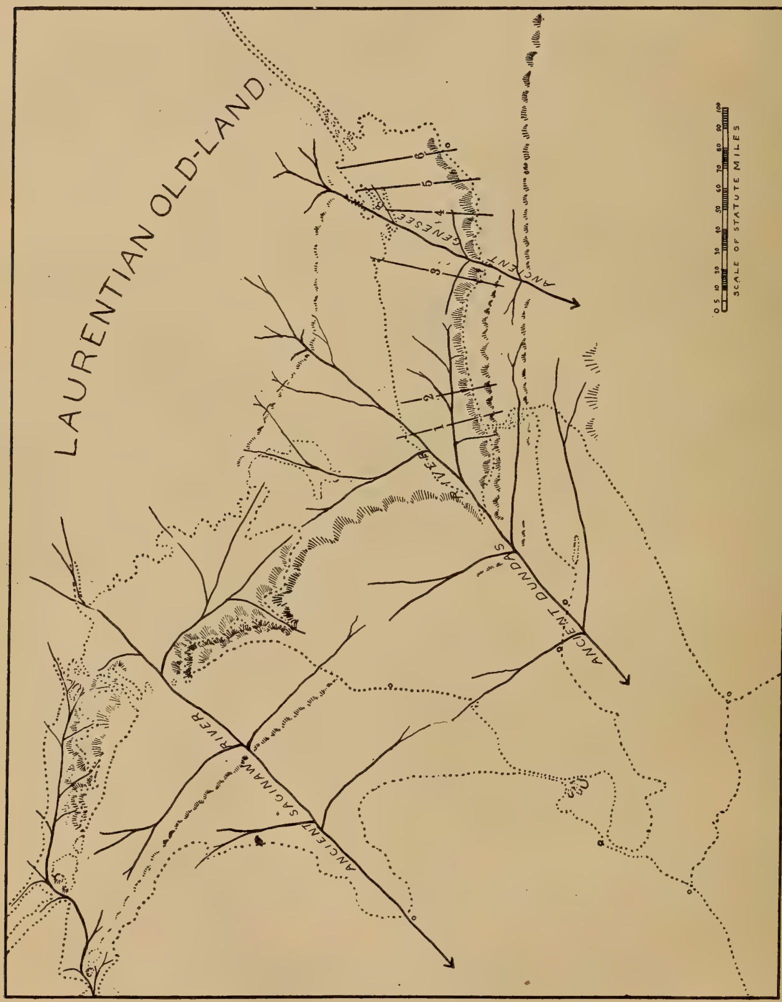


Fig. 5 Diagram showing type of drainage existing in Tertiary times in the Laurentian region.[1]

[1]These maps are intended merely to illustrate the *kind* of drainage, which it is believed existed in preglacial times in the Laurentian region. The ancient consequent streams are probably correctly located; yet it must be stated that the region between Hamilton and Port Stanley has not been sufficiently explored to make the course indicated certain. These consequents may have had a more indirect course, for if the country was worn down to peneplain condition, as appears to have been the case, these streams may have learned

these two points. On the southern shore of Lake Erie borings have revealed numerous deep channels. Thus the bottom of the ancient channel of the Cuyahoga river is reached, according to

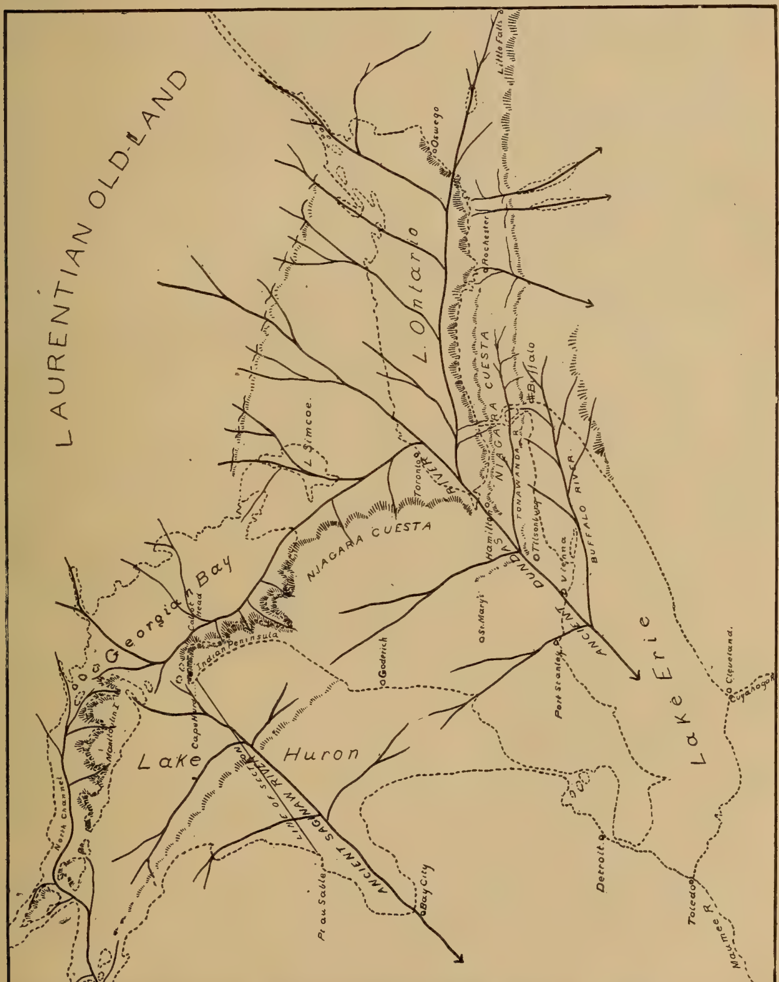


Fig. 6 A hypothetic later stage, showing adjustments which are suggested by existing relief features.

to meander on this surface, the meandering course being retained on re-elevation. The depth of the bed rock at Port Stanley and Vienna, however suggests that a direct channel exists as shown on the map. The principal subsequents are probably located with approximate correctness, but the smaller branches are added without attempt at correctness. They were probably much more numerous than here shown.

Upham,[1] at a depth of more than 400 feet below Lake Erie. Whether this marks the former southward continuation of the preglacial Dundas river or whether that river turned more to the west, following in general the course of the present Maumee, must for the present remain unsettled. The Dundas undoubtedly became eventually tributary to the Mississippi.

**Preglacial Saginaw river.** The existence of an ancient river, flowing southwestward from the Canadian old-land across the valley of Lake Huron and the lower peninsula of Michigan, and finally becoming tributary to the ancient Mississippi, is indicated by the present character of the topography of that region. The Niagara cuesta is breached by a deep channel which now connects Georgian bay with Lake Huron, and which, north of Cove island, an outlier from the Indian peninsula, has been sounded to a depth of over 300 feet. This channel is in direct line with that of Saginaw bay, and, though this latter is at present very shallow, borings at Bay City show an absence of rock to a depth of at least 200 feet below the surface of the bay. At Alma (Mich.) the rock was shown to be absent to a depth of 350 feet below Lake Huron (Spencer); and, as this locality lies to the southwest of Saginaw bay and in line with the trend of its axis, we may assume that our preglacial Saginaw river was located here. Our limited knowledge of the preglacial topography of this region forbids tracing this channel beyond this point. Dr Spencer many years ago traced out this line of drainage, but he assumed that the river which occupied this channel, and which he has named Huronian, flowed northeastward to join that part of the ancient St Lawrence, or Laurentian river, which he supposed to have occupied Georgian bay.

**Preglacial consequent Genesee river.** Among the numerous consequent streams which flowed from the old-land southward or southwestward and which eventually became tributary to the preglacial Mississippi, probably through the ancient Ohio,[2] the pre-

[1] Bul. geol. soc. Am. 8: 7.

[2] Westgate, Lewis. Geographical development of the eastern part of the Mississippi drainage system. Am. geol. 1893. 11:245-60. The Ohio, according to Newberry, flows nearly throughout its entire course in a channel, the rock bottom of which is nowhere less than 150 feet below the present river. The rocks at the "falls of the Ohio" show that at that point the river is not following the ancient course.

glacial Genesee river is the only other that can be mentioned here. Though now flowing northward on account of the tilting of the land, we may assume that much of its valley was carved by a southward flowing stream, the bottom of which, as shown by borings, was considerably below the floor of the present river. Whether Irondequoit bay is a part of this ancient channel, or whether it marks the position of an obsequent stream, must remain for the present an open question. Soundings in Irondequoit bay show a depth of 70 feet, though the rock bottom is probably much deeper.

As soon as the consequent streams began cutting down their valleys again after the continental uplift which followed the period of peneplanation, the lateral subsequent streams began once more to open out broad lowlands in the weaker beds which now had become extensively exposed. These lowlands, in part now filled by drift deposits, are the Ontario and Georgian bay valleys, the latter continued in the North Passage, all carved out of the weak Medina and Lorraine shales; the Tonawanda-Chippewa valley, with the deeper portion of the Huron valley farther west, carved out of the soft shales of the Salina group; and the valley of Lake Erie cut out of the softer middle and upper Devonic shales. A few of these may be considered in greater detail.

**Ontario valley.** It is a well known fact that Lake Ontario is deeper in its eastern than its western part. In the following six cross-sections (fig.7), constructed from the lake survey charts, the greatest depths from west to east are 456, 528, 570, 738, 684 and 576 feet. The section showing the greatest depth is that from Pultneyville to Point Peter light, in the eastern third of the lake. As the present level of Lake Ontario is 247 feet above the sea, the deepest sounding recorded in these sections is 491 feet below present sealevel. From this point of greatest depth, the floor of the lake rises eastward, at first at the rate of 3 feet in the mile, and later at an average rate of 9 feet a mile. The valley appears to be continued south of the Adirondacks in New York along the present course of the Mohawk river, which flows at present several hundred feet above the rocky floor of the valley.[1] This floor ascends eastward, till at Littlefalls

[1] Carll. Pa. geol. sur. $I^3$:363.

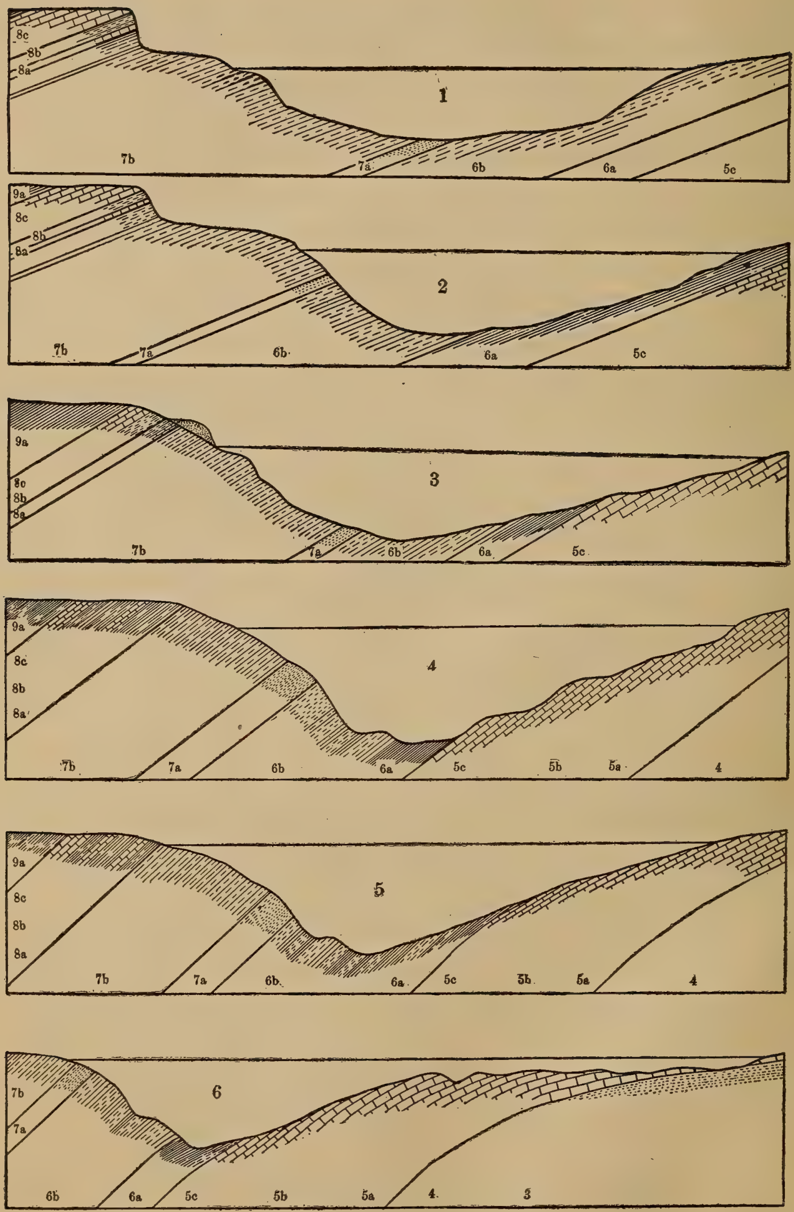


Fig. 7 Six cross-sections of Lake Ontario showing topography and geology. Vertical scale 1 inch = 1280 feet; horizontal scale 1 inch = 15¾ miles. Numbering of beds as in table; location of sections indicated in fig. 5. Section 1) E. of Niagara to E. of Pickering light. 2) Lockport to Darlington light. 3) West of Genesee to Presque Isle light. 4) Pultneyville to Point Peter. 5) West of Fair Haven light to False Buck light. 6) Oswego to Kingston.

the preglacial divide has an elevation of 440 feet above sealevel.[1] The following diagram (fig. 8) shows the present relation of the deepest part of the channel of Lake Ontario to sealevel, and the relation which would result by a tilting of the land back to its probable position in preglacial times. The last profile shows a continuous westward slope of the floor of the valley, steeper in the eastern portion, where the rocks are harder and the valley narrower, and more gentle in the western portion, where the softer rocks have allowed the opening of a broad lowland.

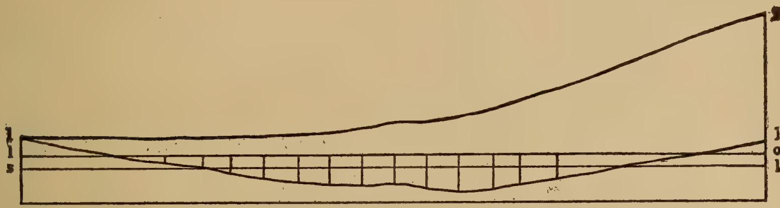


Fig. 8 Diagram showing the present deepest e–w channel of Lake Ontario along line 1–1, and its relation to sealevel s. l. and the level of Lake Ontario l. o. At 1, left side of diagram is represented the bottom of the channel at Vienna, 200 ft below level of Lake Erie or 370 ft above sealevel. At 1, right side, is the divide at Littlefalls 440 ft A. T. The line 1–2, is the line 1–1, but elevated on the east (right) so as to give a continuous westward drainage. Horizontal scale 1 inch = 100 miles. Vertical scale 1 inch = 4000 feet.

Numerous theories have been advanced to account for the deep basin of Lake Ontario. Spencer believed it to have been formed by an eastward flowing stream, the ancient Laurentian river, which received the Erian river as a tributary through the Dundas valley. The eastward continuation of this river Spencer believed to have been essentially along the course of the modern St Lawrence, the present great elevation of the rocky bed of this stream, above that of Lake Ontario, being explained by a warping of the land. Upham also believes that the basin is in part due to warping, but he considers it the valley of a westward flowing stream. Russell also holds this latter view; for he says[2] that, "previous to the glacial epoch, the greater part of the Laurentian basin discharged its waters southward to the Mississippi and . . . during the first advance of the ice from the north the drainage was not obstructed so as to form important lakes". Westgate[3], in tracing out the de-

[1] Bigelow. Bul. geol. soc. Am. 9:183.
[2] Lakes of North America, p. 97.
[3] *Loc. cit.* p. 92.

velopment of the Mississippi drainage system, considers that the flow of the Laurentian drainage system was southward into the predecessor of the Ohio river. As has already been shown, Spencer's eastward flowing river system can be originated only by a complete readjustment of the drainage, resulting from a great relative depression of the eastern uplands. Such a system could only come into existence after the valleys had been formed for it, and hence, as far as the history of the lake basins is considered, no such river system is required, and, unless positive proof of its former existence is forthcoming, it may be dismissed as hypothetic. One of the most important theories of the origin of the Ontario and other lake basins, and one which has had, and still has many prominent advocates, is that of glacial erosion, either entire or preceded by river erosion. This explanation was first most strongly urged by Prof. Newberry, and it has found its most recent able supporter in Prof. Tarr. It is impossible to do full justice to this view in the present limited space. Ice erosion is a factor the potency of which has often been overlooked, but of the importance of which there can be no question. We may however question whether a valley which, like that of Ontario, lies transverse to the general direction of ice movement in this region, can owe much of its depth to this agent. The following considerations will be helpful in understanding the influence of glacial erosion on preexisting topography. If a valley like that of Lake Ontario is occupied by a glacier the motion of which is parallel to the trend of the valley, the topographic relief is likely to be accentuated by ice erosion. If the motion of the ice is transverse to the direction of the valley, the erosion tends to obliterate or at least reduce the relief features. If, however, a mass of ice remains stagnant in the valley, the upper strata of ice may override it, and the amount of glacial erosion is reduced to a minimum. The striae in this region, together with the direction of slopes from the oldland, point to a southward movement of the ice, and Gilbert has shown that the amount of erosion on the edge of the escarpment in western New York is comparatively slight.[1] Hence we may assume that the basin of Ontario was mainly *occupied* by ice during the

[1]Bul. geol. soc. Am. 11:121.

glacial period, but that comparatively little erosion was accomplished. This is farther borne out by minor relief features, such as the benches shown in sections 4, 5 and 6, in the southern wall of the basin, and which probably consist of harder beds which erosion has left standing out in relief. On the theory of glacial erosion, we might expect these to be absent, or at least much less prominent, since ice would hardly show such selective power as is attributable to running water and atmospheric agents.

With the failures of the theories that an eastward flowing stream or glacial ice produced the Ontario valley, we are forced, with Upham, Russell and others, to look on a westward flowing stream as the most probable agent in the production of this valley. As has before been shown, such a stream would be the normal result of a gradual development of a drainage system on an ancient coastal plain of the type here considered.

**Ancient St Davids gorge.** Since the time of Lyell, the old buried channel from the whirlpool to St Davids has played a prominent part in the discussion of the life history of Niagara. For a long time it was considered to be the preglacial channel of Niagara, or its predecessor, the Tonawanda. More recently it has been considered of interglacial age, eroded by an interglacial Niagara, during a temporary recession of the ice sheet from this region, and filled with drift during a readvance of the glacier. The most satisfactory interpretation of this channel however makes it independent of the Niagara, and considers it one of many preglacial or interglacial channels which were formed by streams flowing over the edge of the escarpment and which increased in length by headward gnawing of their waters. This type of stream we have learned to call *obsequent,* its direction of flow being contrary to that of the master stream to which its waters eventually become tributary. An illustration of channel-cutting by streams flowing over the edge of a cliff, may be seen today in the chasm near the Devil's hole, on the American side of the gorge below the whirlpool. This gulch was cut by the little stream known as the Bloody run, which during the summer season dries away entirely.

The St Davids gorge has a width of nearly 2 miles at the edge of the escarpment. As will be seen by a glance at the map, it nar-

rows perceptibly southward, till at the whirlpool its width is less than the average width of the Niagara gorge. What the depth of the gorge is has not been determined, though from the depth of the whirlpool, we may assume that its floor is 200 feet or more below the level of Lake Ontario. At, and to the north of the escarpment it probably equals in depth Lake Ontario, opposite to it. The channel is undoubtedly much more irregular than is shown on the map, the sides being probably much diversified by lateral gullies. The great width of the channel at St Davids may perhaps be due in some small degree to widening by glacial erosion; for we know that the channel was occupied by ice, from the glacial scratches which are preserved on its walls, where these are exposed in the present ravine of Bowman's creek near the whirlpool. The influence of this buried channel on the direction and width of the Niagara gorge will be discussed later.

**Valley of Georgian bay.** Georgian bay is in many respects the analogue of Lake Ontario. Like the latter, it also occupies a valley lying between the Niagara escarpment and the crystalline old-land on the northeast. As has previously been shown, the Niagara escarpment extends northward from Hamilton into the Indian peninsula between Georgian bay and Lake Huron, and, after passing the Cove island channel, it reappears in the northwestern face of Grand Manitoulin island. At Cabot's head, on the Indian peninsula, the escarpment rises to 324 feet above the surface of the water, while just off the promontory soundings show a depth of 510 feet, thus making the total hight of the escarpment at this point 834 feet. In some places the summit of the escarpment rises to an elevation of 1700 feet above tide, or more than 1100 feet above Georgian bay (Spencer). The depth of the transverse channel connecting Georgian bay and Lake Huron has been found to be 306 feet, which is more than 200 feet less than the depth of the channel of Georgian bay. It is possible however that the soundings do not show the absolute depth of the rock bottom in the channel; for there may be a filling of drift which raised the bottom of the channel above that of the bay.

The valley of Georgian bay is continued northwestward in the channel known as North passage, a narrow body of water lying between the Manitoulin islands and the Canadian old-land. The southward continuation of the lowland is blocked by drift; but a number of borings, between the southern end of Georgian bay and Lake Ontario, east of Toronto, have developed the existence of a buried channel, which connects these two valleys. This channel is considered by Spencer to mark the pathway of his former Laurentian river. It is clear however that this valley is merely the buried connecting part of the inner lowland which extends along the base of the entire Niagara escarpment. This portion of the lowland was originally occupied by two streams flowing, the one northwesterly into the ancient Saginaw, the other southeasterly into the Dundas. The divide between the two may have been in the neighborhood of Lake Simcoe. It is however not at all improbable that the tributary of the Dundas may have, owing to favorable conditions, gained an advantage over that of the Saginaw, and pushed the divide northward. Such a migration of the divide might have resulted in the diversion of the upper waters of the Saginaw by capture, so that they eventually became tributary to the Dundas. This would account for the greater depth of the Georgian bay lowland, which, after the capture of the upper Saginaw waters, could be deepened independently of the notch in the cuesta through which its waters were formerly carried out. This of course is merely suppositional, and the truth can be established only by more detailed study of the ground. It is however what we might expect to happen in the normal adjustment of a coastal plain drainage. This hypothetic relation is illustrated in fig. 6.

**The Huron lowland and the Chippewa and Tonawanda valleys.** On the yielding strata of the Salina group a second lowland was carved out by subsequent streams, leaving an escarpment capped by the Devonic limestones on the south. This, as we have seen, becomes prominent eastward in the Helderberg range, where the third upper Devonic escarpment unites with it. In the Niagara region it faces the Tonawanda and Chippewa lowlands, which were probably opened out by a subsequent stream tributary to the an-

cient Dundas river. Throughout western Ontario this escarpment is buried by drift, but its presence is indicated by borings, which also prove the continuance of the lowland accompanying it. This escarpment, the inface of the second cuesta, becomes a very prominent feature in Lake Huron, where it is entirely submerged. It is however perfectly traceable from north of Goderich in Canada to the island of Mackinaw. Soundings prove it to have a hight of from 350 to 500 feet or more above the lowland which it faces. This lowland constitutes the deeper portions of Lake Huron, the shallower southwestern area being a part of the upland drowned by the backward setting of the water over the top of the escarpment. The following cross-section (fig. 9) from Point au Sable, north of Saginaw bay, to Cape Hurd, the northern extremity of the Indian peninsula, passes across the highest portion of this escarpment at the 9 fathom ledge and diagonally across the deepest portion of the Huron lowland, where the soundings reach a depth of 750 feet. This apparently marks the location of the preglacial Saginaw river, which probably breached the second cuesta to the south of the 9 fathom ledge, though no channel is indicated by the soundings.

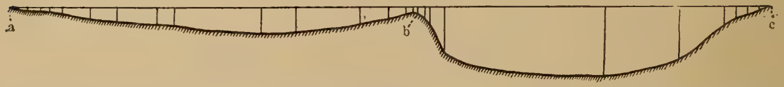


**Fig. 9 Section across Lake Huron from Point au Sable, a) across 9 fathom ledge, b) to Cape Hurd, c) (For location of section *see* fig. 6).**

We have now traced the development of the topographic features of the Niagara district, and have found this to be in conformity with the laws governing the normal development of drainage systems on an ancient coastal plain. The only abnormal features which need to be considered now are the tilting of the land and the filling of most of the old channels by drift, converting the lowlands into lake basins and reversing the drainage of the unfilled channels. These were the catastrophes which immediately preceded the birth of Niagara and which were directly responsible for its existence. To these and the life history of Niagara, attention will now be invited.

Plate 5

" Rock of Ages ", the largest of the fallen limestone fragments at the foot of Luna falls, on the American side (Copyright by Underwood & Underwood, New York)

*Chapter 2*

# LIFE HISTORY OF NIAGARA FALLS

## Glacial period

Two important events immediately preceded the birth of Niagara. The first was the formation of a series of great lowlands and cuestas by stream and atmospheric erosion during a period of time when, according to all indications, the land stood from 2000 to 5000 feet higher than it does now. This was outlined in the preceding chapter. The second event was the accumulation of a great mantle of glacial ice over most of northeastern North America, and the modifications of the previously formed erosion topography, either by the erosive action of the ice or by deposits left on its melting. The time equivalent of the latter event is commonly known as the glacial period of the earth's history, a remote period as time is ordinarily counted, but a very recent one in the chronometry of the geologist. Contemporaneous with this great accumulation of ice was probably the subsidence of the northern part of this region, thus changing the slope of the land surface from a southward to a northward one.

The greatest accumulation of ice during the glacial period appears to have been in the region to the north and northeast of the great lakes, or in general over the area of the Laurentian old-land. The immediate causes which brought about such accumulation, were the extensive refrigeration of the climate and the increased precipitation of moisture, so that a greater amount of snow fell during the winter seasons than could be removed by melting during the succeeding summers. The partial melting and refreezing of the snow, which continued over a long period of time, eventually resulted in producing glacier ice, after the manner of the formation of glaciers at the present time.

The thickness of the great Laurentian glacier, which eventually covered all the land of this region, including even the highest mountains, must be estimated at thousands of feet in its central part with a progressive diminution of thickness toward the margin. The ice

of glaciers, as is well known, has a certain amount of plasticity and will flow under the pressure of its own weight, somewhat after the manner of a mass of pitch. The flow of the great Laurentian glacier was outward in all directions from the center of accumulation, local topographic features exerting a deflecting influence only in the more attenuated marginal portions. In its basal portions, the ice was well supplied with rock debris, from the finest rock flour and clay to boulders often of very great size. This material was derived from the surface over which the ice flowed, and it measured in part the amount of erosive work which the ice had accomplished. The rock fragments frozen into the bottom of the moving ice mass, served as efficient tools for grooving and scratching the bedrock over which the ice flowed, while at the same time the finer material smoothed and polished the rock surfaces. The direction of the grooves and striae on the rock surfaces in general indicate the direction of the movement of the ice which produced them, but this may not always represent the direction of general ice movement for the region, since, at the time of making the striae, the ice may have been thin enough to be influenced by the local topographic features of the region. In the Niagara district the striae have a direction extending about 30° west of south (Gilbert) which direction, being inharmonious with the trend of the lowlands, indicates that these striae were formed by the general movement of the ice, rather than by local movements, controlled by topography.[1]

While the surface rocks of this region were everywhere scratched and polished by the ice, these markings are only exhibited where the protecting mantle of loose surface material or drift has been recently removed. For where the polished rock surfaces are exposed for any considerable period of time, weathering usually obliterates these superficial markings. The best place in which the striae of the region about Niagara river may be studied is near the quarries on the edge of the escarpment, a mile or more west of Brock's monument, where the ledges are progressively uncovered previous to quarrying.

[1] For an account of the glacial sculpture in this region, *see* Gilbert. Bul. geol. soc. Am. 1899. 10:121.

Throughout the greater part of the district, the polished rock surfaces are covered by a coating of drift of very varying character and thickness. This was the ground moraine or till of the Laurentian glacier, and represents the rock debris which was frozen into the bottom of the ice, and carried along in its motion, till liberated by the melting of the ice. This ground moraine, either in its original heterogeneous character or modified by the agency of running water, filled most of the old river gorges through which the drainage of preglacial times found its exit. Some of the shallower lowlands, like that of the Tonawanda, were also filled with drift, while the more profound ones, like the Erie and Ontario lowlands, received only a partial drift filling.

The partial obliteration of the old drainage channels, which was thus brought about, together with a depression of the land on the northeast to a depth below that at which it now stands, converted the unfilled lowlands into lake basins, apparently reversed the drainage of many streams, forcing them to cut gorges where their old channels were drift-filled, and finally became the immediate factors in the formation of Niagara.

### Lacustrine period[1]

During the slow melting of the glaciers in the Laurentian region, and the resultant northward retreat of the front of the ice, large bodies of water, of varying depth and extent, were held in front of the ice sheet, which formed a dam across the northeastern part of the lowland country, the general slope of which was now toward the ice instead of away from it. The elevations of these glacial lakes were determined by the lowest uncovered passes in the margins of the lake basins across which the discharge took place, and, as during the continued melting of the ice dam, lower passes were progressively uncovered, the outlets were successively transferred to them and the levels of the lakes sank correspondingly.

[1] For a detailed account of the successive stages in the development of the great lakes, the shore lines, outlets and extent of each, the reader is referred to the papers by Gilbert, Spencer, Taylor, Leverett, Fairchild and others, cited in the appendix.

Though of a temporary nature, these bodies of water endured sufficiently long to permit the formation of well marked beaches with their accompaniment of bars, sand-spits and other wave-formed features. These have been carefully studied and mapped by a number of observers, and the general extent and outline of these lakes is today pretty accurately determined.

The largest of these glacial lakes, though not the first to come into existence, was glacial Lake Warren. "At its maximum extent Lake Warren covered the south half of Lake Huron, including Saginaw bay, the whole of Lake Erie and the low ground between it and Lake Huron; extended eastward to within twenty or thirty miles of Syracuse, N. Y. and probably covered some of the western end of Lake Ontario."[1] The retaining ice wall on the east extended in a northwesterly direction, across western New York, Lake Ontario and the northeastern end of Lake Huron. This position of the ice front is in part inferred from the existence of moraines of sand and gravel along a portion of that line. The total area of this ancient lake has been variously estimated as including from one hundred thousand to two hundred thousand square miles of surface but this estimate is based on the assumption that the lake occupied the greater part of the area of the present upper Great lakes, with the intervening land, a supposition which Taylor holds to be incorrect. The area of Lake Warren was probably less than 50,000 square miles, or approximately half that of the state of Kansas. The extent and level of this lake was not constant, there being many oscillations, due chiefly to warpings of the land surface. These oscillations are recorded in the various beaches which have remained to the present time. The chief outlet of Lake Warren was by way of the Grand river valley into the valley of Lake Michigan, the southern end of which was then much expanded and occupied by the waters of "Lake Chicago." The outflow of this lake was to the Mississippi by way of the Illinois river, across the divide near where Chicago now stands, thus temporarily reestablishing the southward drainage of this region.

[1] Taylor. A short history of the Great lakes, p. 101.

As the ice front continued to melt away, retreating northeastward, drainage at a lower level was permitted along the ice front to the Hudson valley, and the sea. As a result, the water level sank, the Chicago outlet was abandoned, and Lake Warren became much contracted and in part cut up and merged into new bodies of water. The largest of these was glacial Lake Algonquin, which occupied the basins of the three upper Great lakes, and seems to have been for a long time independent of Lake Erie, which after the division of Lake Warren was for a time much smaller than it now is. (Fig. 11 and 13)

The critical period in the development of the lakes, with reference to the birth of Niagara, was the uncovering of the divide at Rome (N. Y.) and the consequent diversion of the drainage into the present Mohawk valley. This brought with it a subsidence of the waters north of the Niagara escarpment to the level of this outlet, which was considerably below that to which the other lakes could subside, owing to the rocky barriers which kept them at greater altitudes. As a result Niagara river came into existence, though at first it was only a connecting strait between Lake Erie and the subsiding predecessor of Lake Ontario. The overflow from Lake Erie occurred at the present site of Blackrock, because there happened to be the lowest point in the margin of the lake. It is not improbable that a small preglacial stream had predetermined this point, either flowing southward into the river occupying the Erie basin, or northward as an obsequent stream into the Tonawanda. The course of the river below Blackrock was determined by the directions of steepest descent of the land surface, which was probably predetermined to some extent by preglacial streams. As soon, however, as the level of the waters of the Ontario valley sank below the edge of the Niagara escarpment at Lewiston, a fall came into existence, which daily increased in hight as the level of the northern lake was lowered. From that time to the present, Niagara has worked at its task of gorge-cutting, the present length of the gorge, from Lewiston to the falls, marking the amount of work accomplished.

When the waters north of the escarpment had subsided to the level of the outlet at Rome, a long period of stability ensued, during which extensive and well marked beaches were formed by the waves. This comparatively long-lived body of water has been named Lake Iroquois, and its outline is shown in the accompanying map (fig. 10) reproduced from Gilbert's *History of the Niagara river.* The Iroquois shore lines in this region may be seen in the ridge road which extends eastward from Lewiston, and westward from Queenston, closely skirting the foot of the escarpment.

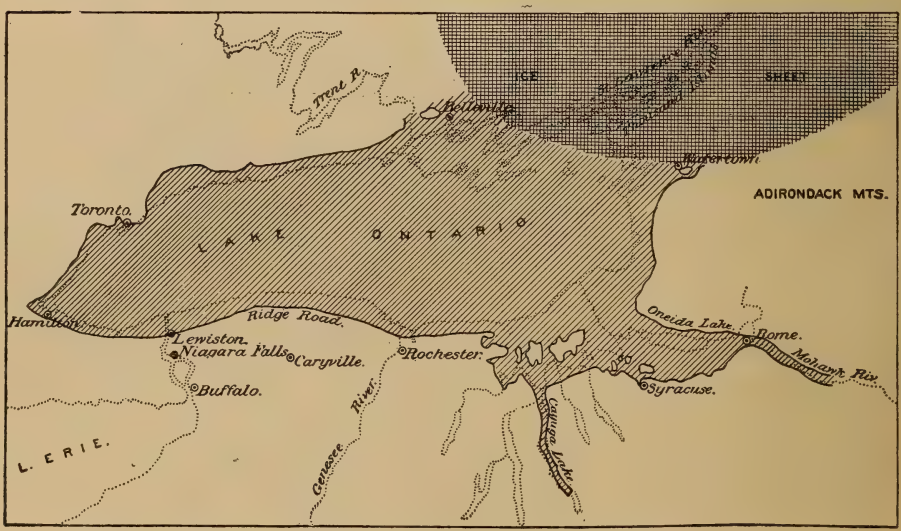


Fig. 10 Map of Lake Iroquois; the modern hydrography shown in dotted lines. (After Gilbert)

A fine section of this old beach is seen just behind the railroad station at Lewiston. Here the layers of sand and gravel slope steeply toward the southeast, and many of them are irregular and wedge-shaped. Some of the beds, a foot or more in thickness, consist entirely of rounded pebbles, with little or no sand between, forming a porous mass of "loose gravel". The prevailing rock of the pebbles is the Medina sandstone, derived from the neighborhood, and the pebbles are always well waterworn, and commonly of the flattened type characteristic of thin bedded rocks. Mingled with the beds of coarse material are layers of fine sand, the structure of which is well brought out by exposure to wind and weather. Not

infrequently masses of sand and pebbles are cemented into a conglomerate by calcite or other cementing agents.

The terminal portion of the beach at the Lewiston station is rather exceptional. It has here the character of a sand spit, extending toward the Niagara river. Between this spit and the escarpment there is a low area of irregular outline, something over half a mile in width along the river and extending perhaps three fourths of a mile eastward from it. This area is bounded by steep erosion cliffs of unconsolidated material, and is from 30 to 50 or more feet lower than the level of the ridge road. The suggestion presents itself, that these features may be due to the current of the Niagara at its *embouchure* into Lake Iroquois, at a time when the falls were probably not far distant. (*See* plate 3 and map)

There is evidence that the level of Lake Ontario at one time stood much lower than it does at present; for the bottom of the lower Niagara, from Lewiston to the lake, is from 100 to 200 feet below


**Fig. 11** Gilbert's map of the Great lakes at the time of the Trent river outlet. Modern hydrography dotted.

the present water level. In fact, the old beaches about Lake Ontario indicate a number of oscillations of level, similar to those recorded in the other glacial lakes, and due chiefly to crust warpings.

Lakes Algonquin and Iroquois were probably contemporaneous, and it is believed that for a time the former discharged its waters to the latter by way of Balsam lake and along the course of the Trent river. This discharge by way of the Algonquin river, as this old outlet of Lake Algonquin has been called, robbed the Niagara river of seven eighths of its water supply, which up to then had reached it by the present course through the Detroit river. As a result, the volume and erosive power of the river were for a time enormously diminished. (Fig. 11 and 13)


Fig. 12 Gilbert's map of the Great lakes at the time of the Nipissing outlet. Modern hydrography dotted.

During the farther retreat of the ice front, a still lower pass was opened by way of Lake Nipissing and the Mattawa river into the Ottawa. By the time this outlet was opened, the ice had also disappeared from the St Lawrence valley, and the outlet of the waters of the great lakes was transferred from the Rome channel to the one at the Thousand islands, Lake Iroquois at the same time subsiding to Lake Ontario. (Fig. 12 and 14)

The successor of Lake Algonquin, after the change from the Balsam lake to the Nipissing lake outlet, has been named by Taylor, Nipissing great lakes, while the river which carried its discharge to the Ottawa was called by him the Nipissing-Mattawa (fig. 14).

With the gradual melting away of the great ice sheet, the land on the northeast began to recover from its last great depression,

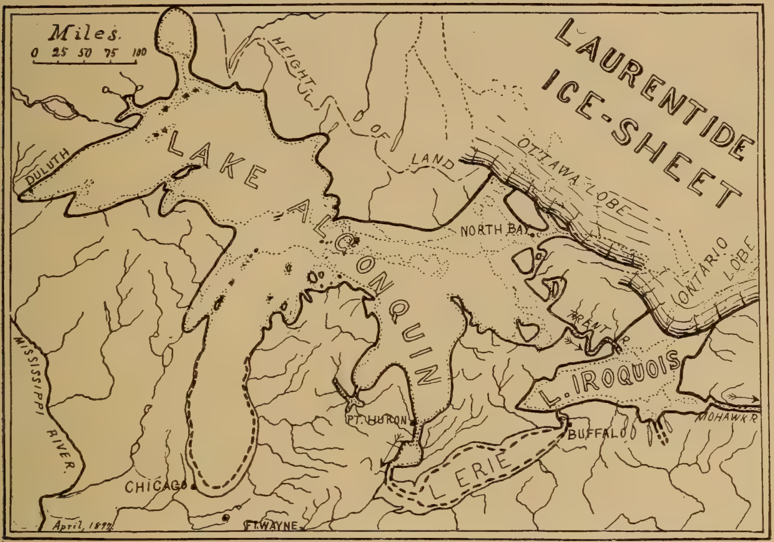


Fig. 13 Taylor's map of Lakes Algonquin and Iroquois.

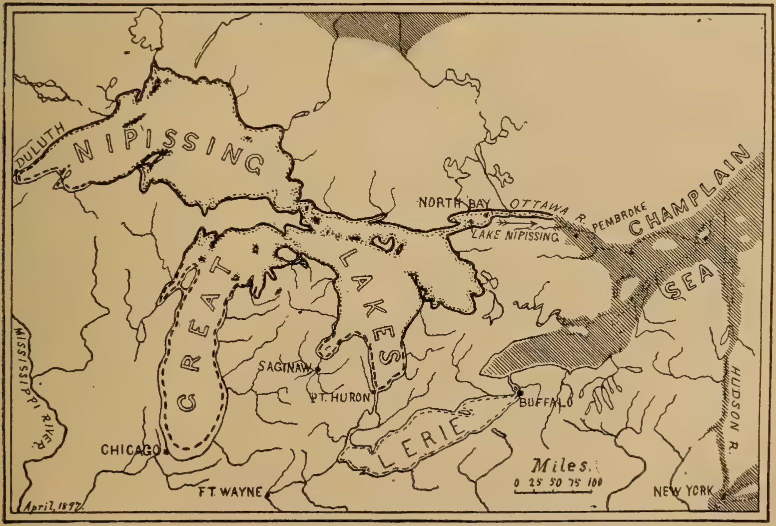


**Fig. 14 Taylor's map of Nipissing great lakes and the Champlain submergence.**

and, though there had been many oscillations, the balance of change was toward a slow but steady elevation of the Laurentian region. As a consequence the beaches of the old glacial lakes, which of

course had a uniform elevation while forming, are no longer of uniform hight above sealevel, but rise progressively toward the northeast. This slow rising of the land caused a gradual canting of the basins, which brought with it a relative fall of the waters along the northeastern shores and a corresponding relative rise of the waters along the southwestern shores. Such a progressive change eventually carried the Nipissing and Balsam lake outlets above the level of the outlet at Port Huron, and the present drainage was reestablished. As the canting affected the Erie basin as well as the others, it caused a progressive elongation of that lake toward the southwest, thus finally giving it its present size and shape. This same canting also resulted in the farther separation of the upper lakes into their present divisions.

While this general outline of the lake history is held by many geologists, others, notably Upham, combat it strongly. Mr Upham holds that the elevation of the land in the northeast had progressed to such an extent by the time the ice had uncovered the northern outlets of Lakes Algonquin and Nipissing, that these passes had been raised above the altitude of the outlet at Port Huron, and that hence these passes never, or but for a brief period of time, served as outlets for the waters of the upper lakes. If this is the case, Niagara always carried the drainage of the upper great lakes as well as Lake Erie, and its volume was approximately uniform throughout its history. The strong erosion features, however, which are found in the Mattawa valley indicate that a large stream discharged here for a considerable period of time; and, if such was the case, it is highly probable that the present Port Huron outlet was not then utilized, and that consequently the Niagara was robbed of the discharge of the upper lake area. The influence on the erosion of the gorge by such a withdrawal of the water must have been a pronounced one, and we shall see later that certain portions of the gorge may well be explained by this hypothesis. During the time of the overflow of the upper waters by way of the Nipissing-Mattawa river it is not improbable that, as held by Taylor and others, the sea had access to the St Lawrence and Ontario basins and possibly to the basins of the upper lakes. This would account for the occurrence of marine types of organisms in the deeper portions of some of the present

great lakes as well as for the maritime species of plants found in the lake district. It must however be borne in mind that this marine invasion was not till after the time of Lake Iroquois, for fresh-water fossils have been found in the beaches of this lake.

The tilting of the land, which is recorded in the deformed beaches, has not yet ceased, as recent investigations in the lake regions clearly prove. Mr Gilbert has made an extended study of this problem; and he has been led to the assumption "that the whole lake region is being lifted on one side or depressed on the other, so that its plane is bodily canted toward the southsouthwest, and that the rate of change is such that the two ends of a line 100 miles long and lying in a southsouthwest direction are relatively displaced .4 of a foot in 100 years". From this it follows that "the waters of each lake are gradually rising on the southern and western shores or falling on the northern or eastern shores, or both". This implies of course a drowning of the lower courses of all streams entering these lakes from the southwest and an extension of those entering from the northeast. Assuming that the rate and character of change will be constant in the future, the following interesting results have been predicted by Mr Gilbert. The waters of Lake Michigan at Chicago are rising at the rate of 9 or 10 inches a century; and "eventually, unless a dam is erected to prevent, Lake Michigan will again overflow to the Illinois river, its discharge occupying the channel carved by the outlet of a Pleistocene glacial lake. . . Evidently the first water to overflow will be that of some high stage of the lake and the discharge may at first be intermittent. Such high water discharge will occur in five hundred or six hundred years. For a mean lake stage such a discharge will begin in about one thousand years, and after one thousand five hundred years there will be no interruption. In about two thousand years the Illinois river and the Niagara will carry equal portions of the surplus water of the great lakes. In two thousand five hundred years the discharge of the Niagara will be intermittent, falling at low stages of the lake, and in three thousand five hundred years there will be no Niagara. The basin of Lake Erie will then be tributary to Lake Huron, the current being reversed in the Detroit and St Clair channels."[1]

[1]Gilbert, G. K. Recent earth movements in the great lake region. 18th an. rep't U. S. geol. sur. 1896–97. pt 2.

### Fluvial period

Niagara falls came into existence when the waters of Lake Iroquois, the predecessor of Lake Ontario, fell beneath the level of the escarpment at Lewiston. At first it was only a small cataract, but day by day, as the lake subsided, it gained in hight and consequently in force of fall, as well as efficiency in cutting its channel. That the entire gorge from Lewiston to the present falls is the product of river erosion is scarcely questioned by any one today, but there are excellent reasons which lead some to believe that this cutting was not wholly the work of the Niagara. When the falls were at Lewiston, the Niagara was a placid stream from Lake Erie to near the falls, much as it is today from Buffalo to the northern end of Grand island. Its banks consisted chiefly of glacial till, into which terraces were cut by the stream, most of which are visible at the present day. The lower ones are well marked in Prospect park, though there they have been grassed over and modified to a considerable extent. From Niagara falls to the railroad bridges at Suspension Bridge, on the New York side of the river, the old bank runs parallel to the edge of the gorge and at a short distance inland from this. From Suspension Bridge to the whirlpool it makes a curve somewhat more crescentic than that of the margin of the gorge, and a similar curve from the whirlpool to Bloody run at the Devil's hole. On the Canadian side these old river banks can be traced from above the falls almost to Brock's monument, and in some cases two or three successive terraces are recognizable. In Queen Victoria park they constitute the steep slope which bounds the park on the west, and parts of which are still actively eroded. Less than a mile below the carriage bridge, the old banks approach close to the modern one and continue, almost coincident with it, to the railway bridges at Clifton. From here to the whirlpool the old river margin has a nearly straight course, while the modern one is curved, and a similar relation holds below the whirlpool, though here, from the great curvature of the modern channel, the old banks are in places nearly a mile distant.[1] (Plate 6)

[1]These old river banks are indicated on the geologic map by dotted lines; the localities where shells have been found are shown by crosses.

Plate 6

Old banks of the Niagara on the New York side, below the railroad bridges (U. S. geological survey)

Within the old channel thus outlined, which was much broader than the modern channel below the falls, accumulations of stratified sands and gravels were formed in the more protected places, much as such deposits are formed in streams today, where sands are swept into protected areas. With these sands and gravels were swept together the shells of those mollusks which lived in the river water, and many of which were of the species now found living in the upper Niagara.[1] Most of the shells thus swept together were probably of dead individuals, though living ones may also have been carried into these growing deposits. Many excavations have been made in these ancient deposits, fragments of which are preserved in various places between the former and present banks of the river. The most notable of these and the one longest known is on Goat island, perhaps a quarter of a mile inland from the edge of the cliff, at the Biddle stairway. In the section opened here, most of the material is seen to be coarse and rudely stratified. The pebbles are subangular, often quite angular, while some appear to be scarcely worn at all. Blocks a foot or more in diameter are not infrequent, the material being generally limestone from adjoining ledges, though fragments of sandstone and of crystalline rocks are not uncommon. Occasionally a lens of fine sand occurs which shows cross-bedding structure, the laminae pointing in a northwesterly direction. The shells are found on the cross-bedding planes, conforming with them, and indicating that they were spread there by the current which moved the sand grains. Among the coarse material the shells are mixed indiscriminately. In many cases the gravels are of the loose type, with scarcely any sand between them, indicating deposition by a powerful current. Along these zones air and water have most readily penetrated, and a deposition of iron oxid has been formed which stains both pebbles and shells. The shells are generally very fragile, and commonly show signs of wear. Gastropods are most abundant in the Goat island gravels.

In Prospect park several excavations formerly exposed these gravels. The deposit here consists of sand and gravel with the pebbles moderately rounded, though occasionally subangular, and

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[1]For descriptions and illustrations of these shells, *see* chapter 5.

varying in diameter up to 6 inches or a foot. The stratification is rude, and shells are abundant. These are mostly fresh-water mussels (Unio, Alasmodonta, etc.) and the valves are generally found in conjunction, a fact which may indicate that these shells lived here. Small gastropod and pelecypod shells are plentifully mingled with the pebbles and sands. Below this are coarser deposits where boulders up to several feet in diameter occur, and below this occurs a bluish clay. In all of these beds shells have been sparingly found.

Several excavations have been made in Queen Victoria park, and here shells are common. The Unionidae appear to be most abundant, though small gastropods are not uncommon. All appear to have been more or less waterworn. The mussel shells are generally decayed, owing no doubt to percolating waters. Below Clifton, the lower of two terraces is of a somewhat sandy character, though many boulders occur in it. Shells of unios occur sparingly in these deposits, and a few small gastropods were found in the lowest terrace. Farther north several excavations in the lower terraces of the old river show loose gravels alternating with a sort of till, a few Goniobasis and other gastropod shells being found here. In some cases the gravels have become cemented into a conglomerate by a deposit of calcite between them, often of considerable thickness. Boulders of similarly cemented gravels are found in the gorge below, at the whirlpool.

It will thus be seen that, throughout the greater part of the young Niagara, deposition was going on as well as erosion. The amount of erosion of the river bed was probably very slight, that of the banks being much more pronounced. The chief part in the cutting of the gorge was enacted by the cataract, which cut *backward* from Lewiston, the amount of *downward* cutting by the river being insignificant. The manner in which the cataract performed its work of cutting may today be observed in both the American and Canadian falls, as well as in waterfalls of other streams falling over strata, the arrangement of which is similar to that obtaining at Niagara. The essentials are a resistant stratum overlying a weak one, the latter being constantly

Plate 7

Cliff on the Canadian side of the gorge, showing the receding base. The giant icicle marks the edge of the overhanging ledge (Copyright by Underwood & Underwood, New York)

worn away by the spray generated by the falling water, thus undermining the resistant layer. Such undermining may be seen in the Cave of the Winds. In course of time this undermining progresses so far that the projecting portion of the capping stratum breaks down for want of support, and the crest line of the fall becomes abruptly altered. The fallen fragments accumulate at the foot of the fall, where they will remain if the force of the water is unable to move them, as illustrated by the rock masses lying at the foot of the American fall. If, however, the force of the falling water is great as at the Horseshoe falls, these blocks will be moved about, perhaps even spun about, and so made to dig a deep channel below the falls. In the soft rocks which lie at the foot of the Horseshoe falls a channel probably not less than 200 feet in depth has been dug in this manner. (Fig. 15)

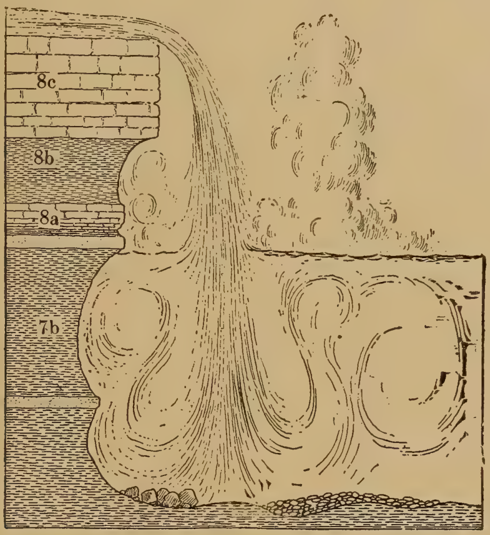


Fig. 15 Sectional view of the Horseshoe falls showing arrangement of strata, and depth of water below falls. (After Gilbert) The numbering of beds corresponds with that of table.

When we consider the Niagara gorge in detail we find it to be much more complex than would at first appear. The first abnormal feature which presents itself in a map view of the entire gorge is the bi-crescentic character of its course, with the rectangular turn at the whirlpool, a course very different from that which we are accustomed to find in large rivers whose direction of flow

has been uninfluenced by preexisting relief features. (Fig. 16) Another feature of importance is the varying width of different parts of the gorge, and the corresponding increase in velocity of current in the narrower parts. The depth of the channel also varies in different portions of the gorge, being in general greater in the wider and less in the narrower parts. (Fig. 18)

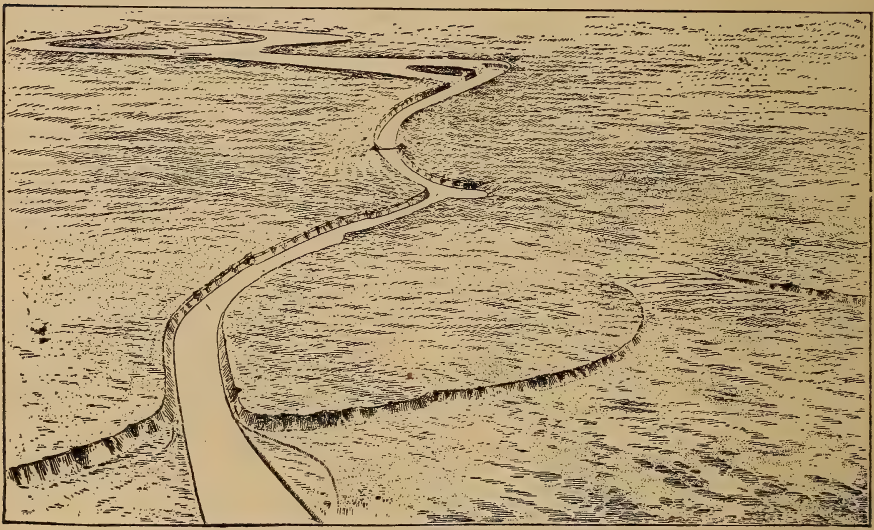

Fig. 16 Birdseye view of Niagara gorge showing the course of the river; the falls, the railroad bridges, whirlpool, location of Fosters flats, escarpment at Queenston and flaring mouth of old St Davids gorge. (After Gilbert)

The first mile and three fourths of the gorge, or that portion marking the retreat from the escarpment to the Devil's hole, extends nearly due south, and is fairly uniform in width, comparatively narrow, and with a current of great velocity. The narrowness of this stretch, when compared with the channel made by the present cataract from the railroad bridges southward, seems to indicate a smaller volume of water during its formation than that now passing over the falls. An alternative hypothesis accounts for the narrowness of this section of the gorge by assuming it to be a preglacial drift-filled channel, made by an obsequent stream flowing northward to the Ontario lowland, similar to that which made the old St Davids channel, but reexcavated by the Niagara. It is highly probable that there was at least a shallow channel which served as

a guide to the young Niagara. The southward continuation of this channel beyond the Devil's hole, is found in the valley of Bloody run, a shallow but distinct depression now followed in part by the Lewiston branch of the New York Central railroad and evidently of preglacial origin, as its floor is covered with till.

Next above this lowest section of the gorge is one, in general much broader, and extending in a southwest direction from the Devil's hole to the whirlpool, a distance of a little less than two miles. This section is contracted near its middle by the projection from the Canadian bank, known as Fosters flats, or Niagara glen. The river is here scarcely 300 feet wide, though the tops of the banks are in places over 1700 feet apart. Above Fosters flats and almost as far as the whirlpool, the river is very calm, and apparently deep, while at the point of contraction at the southern end of Fosters flats, the waters suddenly become tumultuous and rush through the narrow channel with great velocity. This sudden change has been attributed to a sudden decrease in depth of the river at this point, but it is evident that, even if the channel had the same depth as above, the sudden contraction would produce a similar effect, for the waters, spread out over a broad and deep channel, on being suddenly forced to pass through a narrow one, would from mere crowding into a smaller space assume a violent aspect.

### *Niagara glen, or Foster's flats*

PLATE 8

This is one of the most interesting places along the whole Niagara river, though generally little visited by tourists. From the Canadian side a platform of limestone projects, whose surface is a little below that of the general level of the upland plain, from which it is separated by a steep bluff. The platform is known as Wintergreen flat, and, though sparingly wooded, is very deficient in soil. The bluff which bounds it on the west is a part of the old river bank. On the remaining sides this platform is limited by abruptly descending cliffs, at the base of which are extensive talus slopes descending to a lowland of considerable extent. This lowland, which is known as Fosters flats, has its surface well strewn

with huge boulders of limestone. The cliff which limits Wintergreen flat on the northern or downstream side is the highest and most precipitous, and from its base a well marked, dry channel leads northward for a third of a mile to the river's edge. This channel is separated from the present river channel on the right by a ridge which appears to consist of huge limestone blocks, though its base is probably formed by undisturbed remnants of the lower strata of the region. The floor of this old channel is strewn with huge limestone boulders, such as are found at the foot of the American falls today, and its left bank is the precipitous west wall of the Niagara gorge. (Fig. 17)

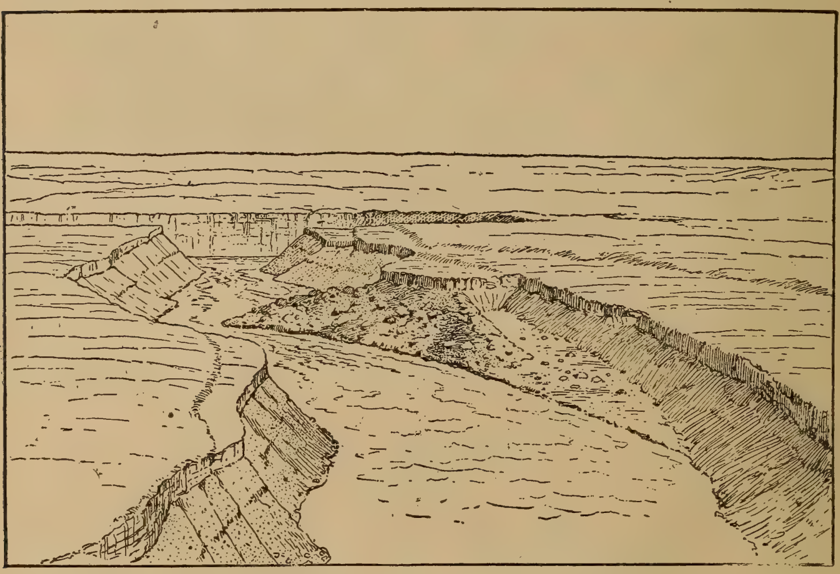

**Fig. 17 View of Niagara glen or Foster's flats, looking south. Forests omitted. (After Gilbert)**

These various features have been well explained by Mr Gilbert,[1] who holds that a narrow island comparable to Goat island, divided the fall in two, when it had receded to the northern end of Fosters flats. The foundations of this island, which has since crumbled away, are seen in the ridge which divides the old dry channel on the left from the main bed of the river. The eastern or American fall at that time was the larger of the two, and it receded more

[1]Nat. geog. monographs. Niagara falls and their history.

Plate 8

Wintergreen Flat looking south; showing the platform which was formerly the river-bed, and the cliff in the center which was once the site of a fall

rapidly. "When the Canadian fall reached the head of the island, the American had just passed it, and part of the sheet of water on Wintergreen flat was drained eastward into the gorge opened by the American fall. The Canadian fall, through the loss of this water, became less active, and soon fell out of the race."[1] By the final retreat of the American fall beyond the southern end of Wintergreen flat, the latter was left as a dry platform with precipitous sides, over which once poured a portion of Niagara's torrent.

While the occurrence of an island in the position pointed out by Gilbert was undoubtedly the immediate cause of the division of the falls, the more fundamental cause, and the one to which the island itself owed its existence, is to be sought elsewhere. From an inspection of the map the suggestion presents itself that there may be a vital connection between the abandoned falls at Fosters flats and the great bend of the river at the whirlpool. When a great river runs for a mile or more in a straight line, as the Niagara does above the whirlpool, and then abruptly turns to the right, the current is deflected by this sudden change in direction to the right bank of the river below the bend, which it continues to hug till again deflected. It is thus that the greatest amount of water will be carried along the right bank of the river, causing a deeper channeling there. When Niagara falls had receded to the present northern end of Foster's flats, the greatest amount of water was carried over its right side. The resulting deepening of the channel on the right, and the consequent drawing off of the water toward that side, was the cause of the appearance of the island (if such existed, as seems probable from the remaining foundation) above the water and the consequent division of the falls. A precisely analogous feature occurs in the lower falls of the Genesee river below Portage. Here, however, no island was formed, though in other respects the two cases are nearly alike. In the Genesee the change has occurred in comparatively recent times, and records of earlier conditions have been preserved. An abrupt bend of the river to the right, deflected the current to the right bank below the bend, and thus caused the deepening of the river bed on that side, as well as the more rapid

[1]Gilbert. Nat. geog. monographs. Niagara falls and their history.

recession of the right hand portion of the falls. In the course of a comparatively short time the channel became so deep on the right, and the falls receded so fast on that side, that all the water was drawn off from the larger portion of the river bed on the left, which today remains as a triangular platform comparable to Wintergreen flat, with steep sides, and several hundred feet wide, at its downstream end. The river now flows in a channel, in places less than 10 feet wide, and 100 feet below the level of the platform which was its bed less than 100 years ago. The present lower fall, having mostly receded beyond the upstream end of the platform, again extends across the entire bed of the river. The water in the river has not, as far as known, changed in average volume, though above and below the narrow part the gorge is many times as wide. All the water which passes in a thin sheet over a broad fall above the narrow gorge is forced to pass through this contracted portion, and presents a rushing current, though the bed is deeper here than where the gorge is broader. The time required for the recession of the fall over the space of the 2000 feet of narrow gorge, must have been much shorter than that required for the recession through a similar length in the broader portion of the gorge, for the concentration of the waters here enabled it to do much more effective work.

Judging by analogy, we may assume that the narrow channel opposite Foster's flats was cut by a stream of the full power of the present Niagara, but whose main mass of waters was carried over the right side of the fall on account of the bend in the stream above. The present Horseshoe falls is cutting a much narrower gorge than that to the north of it, owing to its peculiar position at the angle of a second great bend. (Fig. 19) From the fact that the cutting was most profound on the eastern or right bank of the river at Foster's flats, this bank has received the precipitous character which it has retained to the present day.

An interesting fact bearing on the interpretation of the history of Foster's flats, is the occurrence in the sands among the huge boulders near the foot of the ancient falls, of shells of the small fresh-water gastropod, Pomatiopsis lapidaria Say,[1]

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[1] *See* chapter 5.

which is found living in the Niagara river today, but only on the rocks and boulders lying in the constant spray of the modern cataract.

After passing Foster's flats, the scene of greatest erosive activity seems to have been transferred to the left bank of the river. This is indicated by the verticality of this side of the gorge south of Foster's flats, which suggests active erosion, while the lowland known as Ongiara park opposite to this on the New York side of the river, with its enormous boulders scattered about, recalls the dry channel on Fosters flats or the foot of the present American fall, and suggests an amount of water insufficient to remove them. This may be accounted for by assuming that the nearness of the fall had

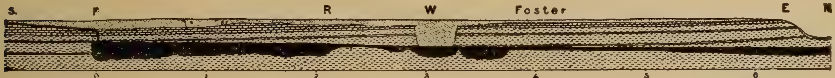


**Fig 18 Longitudinal section of the Niagara gorge from the falls F to Queenston hights E, showing strata of west bank and depth of channel. (After Gilbert) R railway bridges. W whirlpool· Foster = Foster's flats. Figures indicate miles.**

given the river itself greater momentum above the fall, and that hence it dug deeper into the old drift-filled valley of the St Davids at the whirlpool. As a result, the deflection of the current to the right bank became more abrupt, striking the New York bank immediately south of where Ongiara park now is, and, being again deflected toward the Canadian side, it reached this just at the southern end of Foster's flats, thenceforth for a time causing the most active erosion on that side. The washing out of the drift from the old St David's channel furnished the river with tools with which it was able to cut down into its bed, so that in this portion erosion was probably both by backward cutting of the falls and downward cutting of the river above the falls.

We have so far considered the falls as of simple type, but it is by no means certain that such was the case. If we judged from analogy with other streams which have cut gorges in the same strata as those found at Niagara, we should suppose that, as in the case of these streams, a separate fall was caused at Niagara by each resistant layer. Thus in the lower Genesee river, at Rochester, one fall is caused by the upper hard bed of the Medina formation, an-

other by the limestone of the Clinton group, and a third by the Lockport limestone. In the Niagara river we might suppose that at least three, and possibly four, falls had existed at one time. The lowest of these would have been over a hard bed of sandstone, about 25 feet thick, and about 100 feet below the top of the Medina group. Another might have been caused by the hard capping stratum of Medina sandstone, 10 feet thick. A third over the 30 feet of Clinton limestone; while a fourth would have been formed over the Lockport limestone. The second and third would perhaps unite in one, as the shale bed between the two resistant layers is only 6 feet thick. It may however be objected that in a great cataract the force of the falling water is such as to cause uniform recession of all the layers, and that hence only one great fall existed.

### *The whirlpool*

PLATE 9

Perhaps the most remarkable part of the entire gorge is its great swollen elbow, the whirlpool. Here the current rushing in from the southeast with great velocity, circles around the basin and finally escapes, by passing under the incoming current, through the comparatively narrow outlet, in a northeasterly direction. The waters in the whirlpool have probably a depth of 150 or 200 feet, but both the outlet and the inlet are shallow, for here ledges of the hard quartzose bed of the Medina formation project into the river, extending in the latter case probably across the channel. An examination of the walls of the whirlpool basin shows that rock is absent on its northwestern side, the wall here being formed of unconsolidated material or drift. This is best seen on descending to the edge of the whirlpool on the Canadian side, through the ravine of Bowmans creek. It will be observed that the Niagara has here exposed a cross-section of the ancient drift-filled channel which extends southeastward from St Davids. This channel appears to have been that of a preglacial stream of the obsequent type,[1] which was tributary to the streams of the Ontario lowland. Some geologists however, notably Mr Taylor, believe that this old channel may have

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[1] *See* chapter I.

Plate 9

The whirlpool from the Canadian side. The ledges projecting at the water's edge, at the outlet, are the gray band in the Medina

been formed by a river and cataract similar to the Niagara of today, during interglacial time. That this old channel was once occupied by ice is shown by the glacial scratches on the limestone ledges exposed in the western wall of the old gorge, where this has been cleared of drift by Bowmans creek, and it is apparent that the filling in by drift must have occurred after the ice occupation. An inspection of the map will show that a part of the present Niagara gorge, that containing the whirlpool rapids, is in direct continuation of the old St Davids channel, and that, a little above the railroad bridges, the Niagara makes a pronounced bend, which brings it in conformity with the direction of this channel. This suggests that there was at least a shallow depression, the insignificant southeastward continuation of the St Davids channel, which guided the waters of the Niagara in this direction. Here a question of great importance in the history of the Niagara presents itself. Did the ancient St Davids gorge end where is now the south side of the whirlpool, with only a shallow surface channel extending beyond this point, or was the gorge of the whirlpool rapids a part of the old St Davids channel, which was merely cleared by the Niagara of the drift that filled it? The latter condition was assumed to be the true one by Dr Julius Pohlman of Buffalo, a pioneer in the study of the Niagara gorge and the first to recognize the complexity of the channel and attempt to account for its varying character. The theory is still held by many geologists. On the other hand, Taylor and others think it more likely that the ancient gorge stopped where is now the inlet to the whirlpool, and that the gorge above it is the product of post-glacial erosion. If this view be accepted, the narrowness and shallowness of the gorge of the whirlpool rapids must be accounted for by some change in the volume of water during its formation. Taylor, who has studied this problem, has come to the conclusion that, during the time that the gorge of the whirlpool rapids was being excavated, the upper great lakes (then united into Lake Nipissing) discharged by way of the Nipissing-Mattawa river as already outlined, and that therefore Niagara drained only the shallow Lake Erie, the amount of water in the river being only one eighth its present volume. It is easy to see that such a reduc-

tion in volume would lead to a great decrease in cutting power, and that the resultant gorge would hence be much narrower and shallower than the one cut when the water supply was as large as at present. The Nipissing-Mattawa outlet was finally closed, as we have seen, by the elevation of the land on the north, and the upper lakes assumed their modern outlet by way of Port Huron. As a result the water supply of Niagara was greatly increased, and the broad and deep gorge, which extends from south of the railway bridges to the present falls, was cut by a cataract of the size of the present Horseshoe falls, which in addition carried the water now passing over the American falls. This correlation between change in drainage of the upper lakes and change in size of the gorge of Niagara is certainly very suggestive, and seems admirably to account for many features observed in the gorge. For example, it explains satisfactorily the sudden widening of the gorge just before reaching the whirlpool, forming what Taylor has called the Eddy basin, from the strong eddy which characterizes this portion of the river. This wider part of the gorge Taylor believes was formed by the same large-volume river which cut out the broad channel north of the whirlpool, and he farther thinks, that the sudden change from this broad channel to the narrow one of the whirlpool rapids marks the reduction in volume of water on the opening of the Nipissing-Mattawa channel, which had hitherto been blocked by the remnant of the Laurentian glacier. There are however several features which must be satisfactorily explained before this theory (which Upham rejects on grounds already stated) can be accepted. It is highly probable that the gorge of St Davids was worn back beyond the whirlpool. From the great depth of the whirlpool basin, and the presence of the quartzose sandstone bed at the inlet to it, it seems probable that a fall existed here in the ancient stream which carved the St Davids channel. That channel has probably a depth similar to or greater than that of the part now constituting the whirlpool basin. Now, if, as we have reason to believe, this old channel was formed by an obsequent stream of moderate volume flowing northward to the Ontario lowland, it can hardly be assumed that there was but one continuous fall of from four hundred to five

Plate 10


The Whirlpool rapids and American bank, looking north. The talus above the gorge road covers the upper Medina sandstones and shales. The lowest projecting ledge consists of the two Clinton limestones; the talus above that covers the Rochester shales, and the upper cliff is of Lockport limestone. The upper gray Medina projects in one place, and shows the Clinton shale above it.

hundred feet in hight, with such a pronounced alternation of hard and soft layers. We must rather assume that a separate fall existed over each hard layer, and that, as in the other streams flowing northward over these same strata, these falls were separated from one another by considerable distances. If then, as is clearly indicated by the quartzose sandstone ledge at the inlet to the whirlpool, the lowest of these falls was at that place, the other two or three must have been at some distances up stream, and in that case it is not too much to assume with Pohlman, that the upper old falls over the Lockport limestone were somewhere near where the gorge is now spanned by the railway bridges. Taylor, however, does not encounter this difficulty, for he assumes that the St Davids gorge was formed by an interglacial Niagara, the great cataract of which, just before its cessation (probably through a southward diversion of the drainage) plunged as a single fall over the cliff into the basin now holding the whirlpool. To this view it may be objected that the old St Davids gorge is not such as would be formed by a single great cataract, since it flares out northward, having a width at St Davids of perhaps two miles. Such a form is more readily accounted for if one assumes that the valley was made by the headward gnawing of an obsequent stream and its various branches. Taylor meets this objection by invoking the action of readvancing ice to broaden the gorge, but, unless the last ice advance was from a very different direction from that indicated by the striae of this region, this hypothesis will scarcely hold. That direction, as already noted, is 30° west of south, while the direction of the old gorge is almost due northwest. Why may we not assume that only a portion, the southern one of the gorge of the whirlpool rapids, was carved by the Niagara during the time that its volume was diminished, and that the greater portion of this gorge was preglacial? This would greatly reduce the length of time during which the upper lakes discharged by way of the Nipissing-Mattawa river, though probably leaving time enough for the waters from these lakes to produce all the erosion features found in this ancient stream channel. This would still leave the Eddy basin to be accounted for, a difficulty which may perhaps be diminished by assuming that the second of

the ancient falls was situated at the point where the gorge contracts to the width of the narrower channel of the whirlpool rapids.

It will thus be seen that this interesting problem of the origin of the gorge of the whirlpool rapids, propounded nearly 20 years ago by Dr Pohlman, is by no means wholly solved. We may return to the original solution of the propounder of the question or we may find new evidence which will corroborate Taylor's explanation. And who shall say that still other explanations of these features may not be forthcoming in the future, when those now demanding attention will be no longer regarded as plausible or sufficient?

### *The upper gorge and the falls*

PLATES 1, 2, 4, 5, 11

Whatever may be believed with reference to the narrow gorge of the whirlpool rapids, most observers agree that the broad and deep gorge from Clifton to the present falls was made by a cataract carrying the full supply of water. This, the latest and most readily interpreted part of the gorge, has come to an end at the Horseshoe falls of today, and the character of the channel hereafter to be made can only be conjectured. The river has reached another of its critical points, where a rectangular turn is made, and it is not improbable that, as at the other turns, so here the character of the gorge will change. Already a short channel, considerably narrower than that of the last preceding portion, has been cut by the Horseshoe falls. (Fig. 19) This narrowness of the channel is due to the concentration of the water at the center of the stream. It is easy to see that Goat island and the other islands owe their existence to this concentration of the water; for at one time, as shown by the shell-bearing gravels, these islands were under water. The channel above the Horseshoe falls has been cut more than 50 feet below the summit of Goat island at the falls, while the upper end of the island is still at the level of the water in the river.

Goat island lies on one side of the main mass of forward rushing water, which passes it and strikes the Canadian bank, from which it is deflected toward the center of the cataract, which portion is thus deepened and worn back most rapidly. The directions of the cur-

Plate 11

The Horseshoe falls with Goat island and the Three Sisters, as seen from the Canadian side. This view illustrates the narrowness of the gorge now forming.

rents may be seen from the upper walks in the Canadian park, and the effectual erosion of the banks may also be observed. In many cases the shores have been ballasted and otherwise protected against the current. During an earlier period, when the falls were situated farther north, and before the central part of the stream had been deepened to its present extent, the water, then at the level of the river above Goat island, flooded what is now the Queen Victoria


Fig. 19 Crest lines of Horseshoe falls. From the original tracing of the surveys by courtesy of the New York state engineer and surveyor. 1 Terrapin rocks. 2 Former Table rock.

park, and carved from the till the pronounced concave wall which now bounds the park on the west. A local eddy, probably during very recent times, carved the steep and still fresh semicircular cliff which incloses the Dufferin islands.

The fate of Goat island is not difficult to foresee. In a thousand years from now, at the present rate of recession, the Horseshoe falls

will have reached the upper end of the island and will draw off all the waters from the American falls, which by that time will have receded only about half way to the Goat island bridge. All the islands will then be joined by a dry channel to the mainland, an event which was anticipated in the year 1848, when, owing to an ice blockade in the Niagara river near Buffalo, the American fall was deprived of all its waters for a day. As already indicated by Gilbert's forecast, in from two to three thousand years from now, or long before the falls have even reached the head of Grand island, the drainage of the great lakes will be reversed, provided the land continues to rise northward as it has in the past, and Niagara will carry only the drainage of the immediate neighborhood. From a majestic cataract it will dwindle to a few threads of water falling over the great precipice, such as may be seen during the summer season in the upper falls of the Genesee at Rochester.

### Age of Niagara

Speculations as to the age of Niagara have been indulged in ever since men began to recognize that the river had carved its own channel. The length of time required for the excavation of Niagara gorge is not merely of local interest but serves as a basis for estimating the length of time since the disappearance of the Laurentian glaciers from this region, and incidentally it has served as a chronometer for approximately measuring the age of the human race on this continent. From insufficient data Sir Charles Lyell estimated the age of Niagara at 36,000 years, while others have assumed an age as high as 100,000 years or more.

No reliable basis for estimating the age of the gorge was known till a series of surveys were made to determine the actual recession of the cataracts. From these the following variable rates of recession of the two falls have been obtained.[1]

[1] Report N. Y. state engineer. 1890.

*The American falls*

| | Feet a year |
|---|---|
| From 1842 to 1875 | .74 |
| 1875 " 1886 | .11 |
| 1886 " 1890 | 1.65 |
| averaging | |
| From 1842 to 1890 | .64 |

*The Horseshoe falls*

| | |
|---|---|
| From 1842 to 1875 | 2.01 |
| 1875 " 1886 | 1.86 |
| 1886 " 1890 | 5.01 |
| averaging | |
| From 1842 to 1890 | 2.18 |

This shows a most rapid increase in the rate of recession during the four years between the last two surveys. From this we may assume that the mean recession of a cataract combining the volumes of both American and Horseshoe falls, such as existed throughout the greater period of gorge excavation, is at least three feet a year and may be as high as four or even five feet a year.

The first to make use of this known rate of recession in estimating the age of the gorge was Dr Julius Pohlman. He considered that the gorge of the whirlpool rapids and other portions of the present gorge were of preglacial origin, and so reduced the length of post-glacial time to 3500 years. Since that time numerous estimates of the age of the gorge have been made, the results often varying widely, owing to different interpretations given to the narrow portions of the gorge. It is perfectly evident that, if Niagara was deprived of seven eighths of its water supply, for the period of time during which the gorge of the whirlpool rapids was excavated a very slow rate of recession must have obtained, and hence the age of the gorge is greatly increased. Upham, who does not believe in the withdrawal of the waters, makes the age of the gorge between 5000 and 10,000 years. Spencer and Taylor are ardent advocates of the reduction of the volume of water during a prolonged period, when the supply from the upper Great lakes was cut off.

The former makes the age of the gorge in round numbers 32,000 years, the latter places it tentatively at 50,000 years, though recognizing the uncertainty of many of the elements which enter into his calculations. Prof. G. F. Wright has recently applied a most ingenious method to the solution of this question, and one which seems to eliminate the doubtful factors.[1] This method is based on the measured rate of enlargement of the oldest part of the gorge by atmospheric action. The present width of the river at the mouth of the gorge is 770 feet, and Prof. Wright thinks that it was probably not less at the time when the formation of the gorge began. Assuming that the bank at that time was vertical, he finds that since then the stratum of Lockport limestone at the top has retreated 388 feet. Careful measurements show that the total amount of work accomplished here by the atmosphere since the beginning of gorge formation, was the removal from the side of the gorge of a mass of rock constituting in section an inverted triangle 340 feet high and with a base of 388 feet. This would be similar to a mass with a rectangular section of the same hight but with a base 194 feet wide. The rate of waste of the banks was measured by Prof. Wright as accurately as possible and found to be over one fourth of an inch a year, or a total amount of 610 cubic yards of rock from one mile of the gorge wall. From this he finds that 10,000 years is the maximum amount of time required for the entire change which has occurred in the bank since it was left exposed by the recession of the cataract.

The most recent and most detailed estimates of the age of the gorge have been made by Prof. C. H. Hitchcock.[2] He assumes that the present rate of recession is four feet annually, and finds accordingly that the last formed section of the gorge, from the present falls to the point where it suddenly contracts above the railroad bridges, was formed during 2962 years, which closely agrees with Pohlman's estimate. Thus the beginning of the great cataract at the northern end of the upper great gorge "dates back to 1062 B.C., 300 years before the time of Romulus, or

[1] Pop. sci. monthly. 1899. 55:145-55.
[2] Am. antiq. Jan. 1901.

to the reign of King David at Jerusalem." Prof. Hitchcock believes that the gorge of the whirlpool rapids was formed while Niagara drained only the diminished Lake Erie, and he allows a period of 7800 years for the accomplishment of this task. For the erosion of the remaining portion of the Niagara gorge Prof. Hitchcock allows 8156 years. Thus the total length of time required to carve out the Niagara gorge is considered by Hitchcock to be 18,918 years.

The reader should here be reminded that all such estimates are little more than personal opinions, and that they necessarily vary according to the individual predilections as to greater or less power of erosion possessed by the cataract under the given circumstances. The leading questions concerning the extent of the preglacial erosion in this region, and the changes in volume of water during the lifetime of the Niagara, which are of such vital importance in the solution of this problem, are by no means satisfactorily answered. Nor can we assume that we are familiar with all the factors which enter into the equation. There may be still undiscovered causes which may have operated to lengthen or shorten the lifetime of this great river, just as there may be, and probably are, factors which make any estimates of the future history of the river and cataract little more than a mere speculation. We may perhaps say that our present knowledge leads us to believe that the age of the cataract is probably not less than 10,000 nor more than 50,000 years.

*Chapter 3*

## STRATIGRAPHY OF THE NIAGARA REGION

The stratigraphy of the Niagara region, or the succession of fossiliferous beds, their origin, characteristics and fossil contents, has since the time of Hall's investigations barely received cursory attention from American geologists, whose interest has chiefly centered in the problem of the physical development of the gorge and cataract. A careful examination of the strata of this region and of their fossils reveals problems as interesting and profound as those furnished by the gorge and cataract, and many of them are of far more fundamental and far-reaching significance. Profoundly interesting and instructive as is the "Story of Niagara" and of the physical development of the present surface features, it becomes insignificant when placed by the side of that great history of the rise, development and decline of vast mlutitudes of organic beings which inhabited the ancient seas of this region and whose former existence is scarcely dreamt of by the average visitor to the falls. These ancient hosts left their remains embedded in the rocks of this region; and from the record thus preserved the careful student is able to read at least in outline the successive events in the great drama which was enacted here, in an antiquity so remote that it baffles the imagination which would grasp it. But he who would decipher these records must bear in mind the maxim of La Rochefoucauld: "*Pour bien savoir une chose, il faut en savoir les détails.*" A knowledge of details is necessary to an understanding of the stratigraphic and paleontologic history of this region, and there is no better way of obtaining this knowledge than by a close study of the various sections which expose the strata here described.

The strata of the Niagara region belong to the Siluric series of deposits, which accumulated during the Siluric era of the earth's history.[1] Rocks of Devonic age occupy the southern portion of the district, resting on and concealing the Siluric strata which dip beneath them. (*See* fig. 1, p. 19) As has already been noted, all

[1] *See* table in chapter 2.

Plate 12

Tunnel through Medina sandstone; N. Y. Central railroad cut, looking north. First shanty and remains of first Lewiston suspension bridge are shown.

the rocks of this region have a gentle southward dip, which permits the lower members to appear progressively as we proceed northward over the surface of the old erosion plane. We may now proceed to describe the various members of this series in ascending order.

### Oswego sandstone

This, the lowest member of the Siluric, is not exposed in the Niagara region, as its point of outcrop is now covered by the waters of Lake Ontario. (*See* sections 1 and 2, fig. 7) From borings, however, we know its character and thickness, which in this region is 75 feet.

### Medina sandstones and shales

Only the upper portion of this formation is exposed in the Niagara district, where the total thickness is more than 1200 feet.

**Red Medina shales.** The upper beds of this division are the lowest exposed beds in this region. They are bright red sandy shales, generally of a very uniform character, though occasionally a bed which might almost be called a sandstone occurs. Wherever this rock is exposed to the atmosphere, it rapidly breaks down into small angular fragments, which quickly form a debris slope or talus at the foot of every cliff. In the faces of the older cliffs this rock is so friable, that it can readily be removed by the hand, the fragments themselves being easily crushed between the fingers. In the course of time these fragments disintegrate into a fine reddish clay soil, which when wet has a rather tenacious character.

As the lower part of the Niagara river from Lewiston to Lake Ontario is wholly excavated in this rock, it may be seen wherever the banks are kept fresh by the river, or where small lateral streams enter the Niagara. Where erosion is not active, the shale bank is soon reduced to a slope of red clayey soil, which generally becomes covered with vegetation.

A good place for the study of this shale is on the New York side of the Lewiston suspension bridge, where a fresh cut reveals about 50 feet of the rock. The bridge is 65 feet above the river, and the total thickness of red shale above the water at this point is therefore 115 feet. The shale here as elsewhere will be found to be seamed

by whitish or greenish bands, both parallel with and at right angles to the stratification plane. In the latter case they are seen to lie on both sides of a joint fissure, which indicates that the discoloration of the rock, often extending to an inch on either side of the joint, is due to percolating air and water, the latter probably carrying organic acids in solution. The horizontal bands, often several inches in thickness, are probably similarly discolored portions along lines of greater permeability.

No fossils have been found in these shales.

**Gray quartzose sandstone.** The red shales terminate abruptly and are succeeded by a stratum of gray quartzose sandstone, which is very resistant, and wherever exposed, produces a prominent shelf. This rock varies somewhat in different portions of its exposure, but it averages perhaps 25 feet in thickness. This bed is exposed along the gorge from its mouth to the whirlpool, where it forms a ledge at the water's edge, beyond which it passes below the water level. It is well shown at Niagara glen, where a spring of cool water issues from beneath it, near the water's edge. In the bank on the opposite side, where a fine section of the rocks of the gorge is shown, this quartzose bed is seen in its full thickness, lying between the red shale below and the shales and sandstones above. The red shale at the water's edge has crumbled away, leaving the quartzose bed projecting from the wall in some cases to a considerable extent.

The quartzose sandstone usually forms beds of considerable thickness in this region, though near the top of the stratum a number of thin beds generally occur. The best exposure for the examination of this rock is in the quarries opened up in the terrace on which the Lewiston tower of the suspension bridge stands. In these quarries the sandstone slabs often show smooth surfaces, which generally bear markings similar to those formed by waves on a surface of fine sand. These wave marks are found in most of the sandstones of the Medina group, but they are nowhere in this region so well developed as in the upper thin bedded layers of the quartzose sandstone. No fossils have as yet been found in the gray sandstone on the Niagara river, though farther east a similar quartzose rock shows shells of the Medina L i n g u l a on the surfaces of the layers, which also show wave marks.

The succeeding beds of the Medina as well as the Clinton, Rochester and Lockport beds, are best exposed along the railroad cut of the Lewiston branch of the New York Central and Hudson River railroad. This cut is reached from the Lewiston end through a short tunnel cut in the Medina sandstone (plate 12). As the beds dip southward, and the roadbed rises in the same direction, we pass rapidly across all the formations from the lowest to the highest exposed.

**Upper shales and sandstones.** The contact between the quartzose sandstone and the overlying Medina shales is not generally well exposed, except in one place. This is in Evan's gully, the first of the small excavations in the roadbed, made by the streams of water which in the spring time cascade from the banks. The quartzose sandstone forms the bed of the gully below the bridge on which the railroad crosses it, and it also forms the capping rock over which the stream cascades to a lower level.

1 The lowest beds of this division of the Medina are gray shales, 25 feet in thickness and readily splitting into thin layers and generally smooth to the touch, indicating the absence of sand. There are however beds of a more sandy character, even to fair sandstones, interbedded with the shales, and this is particularly the case near the middle of this shale mass. These sandstone beds are similar in character to the quartzose sandstone below the shales, but they occur in thin layers, separated by shaly masses. These same beds are exposed in the cutting which leads to the tunnel on the north, where they are shown near the base of the section. They vary in thickness up to 8 inches, and in some cases contain a few fossils, notably the shells of Lingula cuneata (fig. 81). The shales below the sandstone layers are mostly below the level of the roadbed, the greatest thickness exposed above that, being about 6 feet.

The upper 13 or 14 feet of this shaly series are well shown in the cutting north of the tunnel, where they may be seen above the sandstones just alluded to. These rocks present in places an almost perpendicular wall, where the overlying sandstones have not been removed, while from the rapid weathering of the shale, the capping stone generally projects beyond the face of the shale cliff. The un-

dermining of the upper layers thus results in their ultimate breaking down from non-support, and the resulting fall of rocks may be of a dangerous character. Care is therefore necessary in the examination of these sections, and the warnings of the section guards should always be heeded. These men patrol the tracks continually from early morning till after the last train has passed at night. This is necessary, as the fall of rocks is continuous, and often of such amount as to obstruct traffic for some time. Any one who will watch these cliffs for a time from one of the projecting points where a comprehensive view may be obtained, and note the almost incessant fall of rock particles, will receive an impressive object lesson in the processes by which cliff retreat is effected.

In many cases the shale banks are covered with a coating of red mud carried by rains from the red soil above them. This creates the impression that the color of these lower shales is red like that of the shales higher up in the series, and only after breaking off fresh particles can the true color be seen.

2 These gray shales are succeeded by sandstones and sandy shales, some of the former massive, quartzose and in beds 6 or 7 inches in thickness, separated by shaly layers. The sandstone is gray and often porous, as if it had undergone some internal solution, which suggests that fossils may have been present which were dissolved by percolating waters. Fragments of fossils are occasionally found, but mostly in an unidentifiable condition. Many of the thinner and more clayey beds have raised markings on their under side, which may be indicative of the former presence of seaweeds in the muddy beds of this period. Small black phosphatic pebbles, often very smooth, are not uncommon in some of the layers, and larger masses of black, apparently carbonaceous shale are occasionally found mixed with the sand. In the gray shaly sandstone beds the Medina gastropods and bivalves (pelecypods) occur sparingly, and usually in a poor state of preservation. Some of the thin layers are calcareous, though still containing a large proportion of argillaceous matter. These are generally fossiliferous, the most common organism being a small cylindric bryozoan.[1] Fragments of these

[1] Identified provisionally as Helopora fragilis (fig. 74).

beds with the bryozoan weathered out in relief on their surfaces, may be found at the base of the cliff in the cut north of the tunnel.

3 In the northern end of the section the sandstones and sandy shales have a thickness of about 5 feet, and are in turn succeeded by 6 feet of shale, weathering readily into a clayey earth, which accumulates, as a talus on the underlying sandstone ledges. As in the other shale cliffs, so here weathering causes a more rapid retreat of the shale than of the overlying sandstone, which therefore projects beyond the shale cliff till it breaks down.

These shales are mostly gray, sometimes greenish gray, with occasional sandstone bands. Toward the top they become intercalated with reddish bands, and finally the prevailing color of the shale becomes red.

4 Following these shales is a mass of sandstone from 35 to 40 feet thick and consisting mostly of beds which vary from 4 to 6 inches in thickness. The sandstone is compact and solid, reddish in color or gray mottled with red. The beds are separated by red shaly partings, with occasional beds of red shale 2 to 4 feet thick. About 20 feet above the base of this sandstone mass is a concretionary layer from 1 to 2 feet thick, which appears not unlike a bed of large rounded boulders. These concretions vary in size up to 3 or 4 feet in greatest diameter, and they lie in close juxtaposition, not infrequently piled on each other, thus still more simulating the blocks of a boulder bed.

This sandstone cliff is in general quite perpendicular, and the thin and comparatively uniform layers, which are regularly divided by vertical joint fissures, produce the appearance of a vertical wall of masonry, for which many people, seeing it only from the rapidly moving train, have no doubt mistaken it. The regularity of these successive beds is at times interrupted by a heavier layer, either red or gray and mottled, which may be traced for some distance, after which it thins out and disappears. This thinning out of the layers in one or another direction is a common and characteristic feature of these sandstones, and is a direct result of the irregularities of current action during the deposition of the sands. We may trace a sandstone mass for some distance, and then find

that it disappears by thinning, either bringing the layers above and below it in contact or giving way to a bed of shale.

A careful examination of these individual beds will show the presence of ripple marks in many of them. This indicates moderately shallow water during the accumulation of these sands; for ripple marks are found only down to the depth to which wave action penetrates. These ripples vary greatly in size, a bed about 10 feet above the concretionary layer showing examples in which the crests are from one to one and a half or more feet apart.

The fossils found in these sandstones are the characteristic Medina pelecypods, and the common Medina Lingula cuneata.

5 The thin bedded sandstone layers are followed by 12 or 15 feet of massive sandstones in beds from one to several feet in thickness, and varying in color from reddish to grayish. This rock generally shows strongly marked cross-bedding structure on those faces

**Fig. 20a Cross-bedding in Medina sandstone, Niagara gorge.**

which have been exposed for some time. This structure illustrated in figure 20a, copied from a ledge of this rock, indicates diverse current and wave action in the shallow water in which this rock was forming. While the deposition of the strata was essentially horizontal, the minute layers made up of the sand grains were for a time deposited at a high angle, much after the manner of deposition of the layers in a delta. After a while the activity of the current changed to another direction, and the layers already deposited were in part eroded, or beveled across the top, and new layers, inhar-

Plate 13

Section on N. Y. Central railroad cut south of first shanty, looking south. Medina sandstone at base; gray band of upper Medina; Clinton shales and Clinton limestones are shown.

monious with the preceding ones, were laid down on the eroded surface. This was repeated a number of times, as is shown by the succession of changes in the sandstone layers.[1] This structure is sometimes shown on a large scale, as in the case of a bed shown about 200 feet north of " Milk cave ravine ", the second of the small ravines met with in coming from the north. Here some of the layers are very gently inclined, and may be traced for some distance. They are obliquely truncated, other horizontal beds resting on the truncated edges (fig. 20b). (*See also* plate 14)

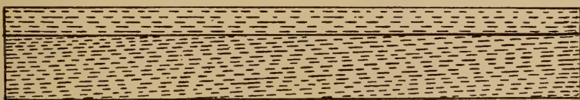

**Fig. 20b Contemporaneous erosion and deposition in Medina sandstone, Niagara gorge.**

The Medina Lingula (L. c u n e a t a) is found in these sandstones as in the lower ones, but other fossils are rare. Occasionally on the sections the hollows left by the removal of the shells may be seen, while similar cavities, caused by the removal of small black pebbles like those found in the lower layers, also occur. In the upper portions of this mass, on the under side of some thin sandstone lenses resting on and separated by shaly partings, occurs the so-called " jointed seaweed " of the Medina formation, known as A r t h r o p h y c u s h a r l a n i, and illustrated on plate 16. This is a characteristic Medina sandstone fossil, but in this region it has not been found in any of the other sandstone strata. Specimens of this fossil were obtained in digging the great power tunnel at Niagara, but only from the sandstone layers near the bottom of the tunnel, which is about the horizon in which they are found in the gorge section.[2]

6 The highest member of the Medina in this region is a hard, massive bedded and compact quartzose sandstone similar to the

[1] Compare with this the cross-bedding structure shown in the unconsolidated sands and gravels in the Goat island gravel pit, and in the section of the old Iroquois beach at Lewiston.

[2] The restriction of this characteristic Medina fossil to these upper layers of sandstone at Niagara was pointed out to me by John MacCormick, the watchman of this part of the road, who collects these specimens and keeps them for sale. As he is continually handling these rocks and has handled them for years, he has become familiar with their characters, and is therefore in a position to obtain knowledge of such facts.

quartzose bed terminating the lower shales. While nearly white when fresh, this rock generally weathers to a grayish yellow color and often exhibits yellow iron stains. On the weathered edges cross-bedding structure is well brought out. When separated from the rocks below by a shaly bed, this rock generally projects from the bank for a sufficient distance to form a shelter for the watchman in case of a sudden shower. Where this sandstone comes down to the level of the roadbed, at a projecting cusp of the cliff, it has been cut through and a portion of it left between the track and the gorge. In the shadow of this rock mass stands the second of the watchmen's shanties which we meet with in approaching from the mouth of the gorge.[1] The upper quartzose bed has here a thickness of 7½ feet. Several hundred feet south of this point, where the top of this sandstone is level with the roadbed, a huge ripple, 15 feet from crest to crest, and nearly 2 feet deep, is shown on the river side of the track. This "giant ripple" was described and illustrated by Gilbert,[2] who found other ripples of similar size in the Medina sandstone at Lockport, as well as in the quartzose sandstone near Lewiston.

On the surfaces of the flagging stones which are derived from the Medina sandstones, ripple marks of small size are not uncommon, and the sidewalks of Buffalo and other cities where this rock is utilized, often exhibit fine examples of such rippled rock surfaces.

In the cliff of Milk cave falls (or St Patrick's falls), which is the second lateral fall below the mouth of the gorge, the upper beds of the Medina formation are well shown. The concretionary layer is near the level of the roadbed, and has a thickness of 3 feet. 29 feet above it is the base of the upper gray quartzose sandstone, before reaching which we find that the red sandstone gradually loses its bright color, at first being mottled, and then at times losing its red color altogether, though the thin partings of shale still retain

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[1] This is occupied by John Garlow, on whose beat most of the "Niagara crinoids" (Caryocrinus ornatus) are to be found. Specimens may generally be obtained from him at a small price.

[2] Bul. geol. soc. Am. 10:135–40, pl. 13, fig. 2.

it. The quartzose capping rock consists at the base of a white bed, from 1½ to 2 feet thick and showing cross-bedding structure, followed by shale 1 to 1½ feet thick and of a reddish color in places, and finally by a solid bed of white quartzose sandstone 5 feet in thickness, and like the lower bed, showing cross-bedding structure on the weathered sections. A few thin layers of sandstone overlie this bed, having a total thickness of less than half a foot. On these follow the shales of the Clinton formation.

The upper Medina sandstones and shales may be traced in both walls of the gorge nearly to the falls. From the southward dip, the beds progressively pass below the water level, till near the falls only a small portion of the upper beds remains. These may be seen at the river margin in the bottom of the gorge, between the *Maid of the Mist* landing and the carriage bridge on both sides of the river. On the New York side only a few feet of the red sandstones are exposed, the remainder being covered by talus. During high stages of the river these exposed beds are covered by the water. On the Canadian side an extensive ledge of the red Medina sandstone is exposed opposite the inclined railway on the New York side. In the banks behind this ledge the white quartzose sandstone which forms the top of the Medina occurs, its top being at least 25 feet above the water level. It here forms a projecting shelf on which rest huge blocks of limestone broken from the cliff above. From this we may judge that at the foot of the Horseshoe falls the upper layers of the Medina may still be above the water level.

### Clinton beds

The Clinton beds at Niagara aggregate about 32 feet in thickness and consist of a stratum of shale at the base and two distinct strata of limestone above this. (*See* Plate 14)

**Clinton shale.** Resting immediately on the quartzose layers which terminate the Medina formation, is a bed of olive green to grayish or sometimes purplish gray shale, which readily splits into very thin layers with smooth surfaces, and is quite soft enough to be easily crumbled between the fingers. Fossils are rare in it, but occasionally layers are found which have their surfaces covered with

crushed valves of small plicated brachiopods, among which Anoplotheca hemispherica and A. plicatula may be mentioned. Other fossils are rarely found except reed-like impressions which are not uncommon. Some impressions have been found which probably belong to Pterinaea emacerata, a pelecypod occurring higher in the Clinton and also in the Rochester shales. The total thickness of these shales is 6 feet.

**Clinton lower limestone.** On the shale rests a stratum of limestone 14½ or 15 feet in thickness. The lower three or four feet of this rock are compact to granular or finely crystalline, having a sugary texture. Small masses of iron pyrites are not uncommon in this rock, this being the only representative of the ferruginous matter so characteristic of this part of the Clinton beds on the Genesee river and eastward, where a well marked bed of iron ore succeeds the shale. Hall[1] states that "the lower part of the limestone, as it appears on the Niagara river, is highly magnesian, and from the presence of iron pyrites rapidly decomposes, giving rise to the production of sulfate of magnesia, which at favorable points along the overhanging mass upon the river bank, may be collected in quantities of several pounds."

Fossils are not uncommon in this division of the Clinton limestone, though the variety is not very great. The most abundant species are a small brachiopod, Anoplotheca plicatula (fig. 133) with a strongly plicated surface, and a larger flat brachiopod, Stropheodonta profunda, which at times seems scarcely more than an impression on the rock surface. The remaining part of this stratum is a massive dark gray limestone with occasional thin bands of a shaly character separating the individual beds. Recognizable fossils are not very abundant in this rock. Many of the thin bedded portions of the lower Clinton limestone contain numerous shining black phosphatic nodules, very smooth and resembling small black pebbles. These are probably concretionary masses, though some have the aspect of being waterworn organic remains. Where the thin limestone layers are covered with a shaly or sandy coating, impressions of the beautiful, little

[1]Rep't 4th dist. 1842, p. 63.

Plate 14

View on the N. Y. Central railroad cut, looking south, just south of the second shanty; the third is shown in the distance. The formations shown are, from below upwards: the top of the upper gray band of the Medina; the Clinton shale; Clinton lower and upper limestone; Rochester shale, and, in the distant cliff, the Lockport limestone

branching seaweed, *Bythotrephis gracilis*, may be found. This occurs also on some of the shaly partings of the limestones. The impressions vary from the slender variety of great delicacy to a coarse one in which the frond consists of broad irregular lobes.

This stratum generally forms a vertical wall with the next overlying stratum projecting beyond it.

**Clinton upper limestone.** In the region of the Genesee river the lower limestone is succeeded by a mass of shale which is generally fossiliferous, and on which lies the upper limestone. In the Niagara region this shale is wholly wanting, the upper limestone resting directly on the lower. The line of separation is however well marked, both by the diverse characters of the two rocks and by the different way in which each resists destruction by atmospheric agencies. The upper stratum is a crystalline and highly fossiliferous limestone, often pinkish in color, though chiefly light gray with yellowish or brownish particles where oxidation has occurred. Portions of the beds consist almost wholly of crinoid stems or joints, which give the rock a coarsely crystalline and sometimes porous aspect. Fossils are abundant in this rock, though the variety is generally not large. The most common species is a rotund variety of the brachiopod, *Atrypa reticularis* (fig. 112), which is generally very robust and sometimes almost globular in form. Of the other fossils in this rock several Stropheodontas may be mentioned, among them *Stropheodonta profunda*. A number of rhynchonelloid shells occur, readily recognized by their pointed beaks and strong plications. Among these are some small specimens of *Camarotoechia acinus*, a species characteristic of the Niagara beds of the west. It is readily recognized by its smooth umbonal area, and its single plication in the mesial depression or sinus, corresponding to which, on the opposite valve occur two plications. Among the more abundant fossils of this rock are smooth elongate and rather strongly biconvex brachiopods of the genus *Whitfieldella*. The most common is W. *intermedia*, but other species occur as well. The thickness of this stratum is 11 feet. The upper beds of this series contain species which on the whole are of a strongly marked Niagaran

type, such as Spirifer niagarensis and others. A common brachiopod is Strophonella patenta, a flat, thin, subsemicircular shell with a straight hinge line and fine surface striations.

A characteristic feature of this upper limestone stratum is the strong development of stylolite structures. These stylolites are vertically striated columns, from a fragment of an inch to several inches in length, and ranged on either side of a horizontal suture or fissure plane in the limestone bed. Projecting from both upper and lower beds, they interlock with each other and so produce a strongly marked irregular suture. This structure is characteristic of limestone beds of this type, but its origin is still obscure. Pressure of superincumbent layers of rock seems to have been the chief cause of their production, this pressure acting unequally on the rock mass, from the presence of fossils or from other causes. A characteristic feature is the open suture at the ends of the columns, which gives the layers the aspect of having separated by shrinkage along an irregular plane. The vertical striations indicate motion either upward or downward.

The Clinton limestones may be seen in both banks of the river where not covered by vegetation, from the mouth of the gorge to within a short distance of the falls, near which they are covered by talus. They always form a cliff in the profile of the gorge, the 6 feet of shale below them forming a sloping talus-covered bank, below which there is another cliff formed by the hard upper Medina sandstone, the lower members forming one or more talus-covered slopes down to the quartzose bed of the Medina. This latter is again a cliff-maker, and generally projects from the bank, while the soft red shale below invariably produces a sloping talus-covered bank. Above the Clinton limestones is another slope and talus formed by the soft Rochester shale, above which a precipitous cliff is formed by the Lockport limestone.

At the base of the cliffs, fallen rocks of the Clinton limestones are mingled with those from the overlying Lockport limestones, and care must be exercised in discriminating between these when collecting fossils. Halfway between the third and fourth watchman's

shanties on the railroad, where the top of the Clinton limestone is on a level with the roadbed, this rock was formerly quarried on the river side, and here a good opportunity is afforded to collect fossils from the limestone fragments. Blocks of the various limestones are also seen by the side of the track between the second and third shanties.

At the whirlpool on the Canadian side the Clinton limestones are seen in both banks of the old St Davids gorge, the section on the west showing glacial striae. Near the foot of the eastern wall of this old gorge and on the talus heaps which flank it, are large masses of calcareous tufa often inclosing leaves, moss or other vegetable structures. These masses appear to come from the horizon of the Clinton limestone, though they have not been seen in place, and it is not improbable that a "petrifying spring" carrying a strong solution of carbonate of lime issues from this rock. Springs issue abundantly from between the two members of the Clinton limestone, and they carry lime in solution, as is indicated by the deposit of soft calcareous ooze on the rocks and other substances over which this water flows. On exposure to the atmosphere this ooze will dry and harden. The joint faces of the Clinton limestone are everywhere veneered over with a thin deposit of calcium carbonate.

*Limestone lenses of the Clinton.* At intervals in the upper Clinton limestone may be seen large lenticular masses of a compact, hard and apparently structureless limestone, often concretionary and not infrequently showing numerous smooth and striated surfaces of the type known as "slickensides" and which are indicative of shearing movements. One of these masses is visible in the bank opposite the third watchman's hut. Its greatest thickness is about 8 feet, and it lies between the upper limestone and the overlying shale, being partly embedded in both. The rock is often cavernous or geodiferous, the cavities when freshly broken being filled by snowy gypsum or grayish anhydrite. Fossils are abundant in this rock.

Several other lenses of this type are visible in the upper Clinton limestone where it is crossed by the Rome, Watertown and Ogdensburg railroad below Lewiston hights. These masses are however

entirely inclosed by the limestone, from which they are differentiated by their structureless character. The lenses exposed on the Rome, Watertown and Ogdensburg road are rich in shells of orthoceratites and shields of trilobites (Illaenus ioxus), while the lens in the gorge yields chiefly brachiopods, the most abundant of which are the smooth Whitfieldellas, the small W. nitida and the larger W. oblata being the most common.

The following species have been obtained from the lens in the gorge:

Brachiopoda

1 Whitfieldella nitida abundant

2 W. nitida oblata abundant

3 W. intermedia common

4 Atrypa reticularis; specimens with strong, rounded bifurcating striae, noded at intervals by strong concentric striae, and apparently intermediate between the typical form of the species as it occurs in the Clinton and upper limestone and A. nodostriata, the most abundant form of the Rochester shales.

5 Atrypa nodostriata; rather common, convex and more elongate than in the shale above, with the plications generally sharper and bifurcating near the front. The pedicle valve has a distinct sinus bordered by strong plications, the corresponding fold being marked merely by strong plications. Anterior margin distinctly sinuate. The nodulations are not well preserved except in specimens from the shaly portions.

6 Atrypa rugosa; several small specimens, both valves very convex, with strongly defined sinus in pedicle valve, in the center of which is a small plication. Plications bifurcate and also increase by intercalation; crossed by strong rugose lines.

7 Rhynchotreta cuneata americana rare

8 Camarotoechia neglecta rare

9 Anastrophia interplicata rare

10 Spirifer niagarensis; common, large and robust, with long hinge line and moderately high area, and strongly incurved beak. The sinus is flanked by two stronger plications and extends to the beak. The plications are flattened on top.

11 Spirifer radiatus; common but generally crushed; with an extended hinge line and form and proportions similar to the preceding species. The striae are fine and flat on top with very narrow interspaces altogether very similar to those covering the plications of S. niagarensis. A scarcely defined plication appears on each side of the sinus in some specimens, and in these the sinus is rather sharply defined and angular at the bottom. In others the sinus is shallow rounded and not definitely outlined by incipient plications. In the more elongated specimens the cardinal angle is well defined, but in the shorter specimens it is rounded.

12 Spirifer crispus rare

13 Spirifer sulcatus rare

14 Dalmanella elegantula; rare and with greater convexity than that of the specimens in the overlying shale.

15 Plectambonites transversalis rare

16 Leptaena rhomboidalis rare

17 Stropheodonta corrugata rare

18 Orthothetes subplanus rare

19 Strophonella patenta rare

Gastropoda

20 Platyostoma niagarensis rare

Trilobites

21 Illaenus ioxus; fragments of caudal and cephalic shields crowded together into masses sometimes of considerable size.

22 Calymene blumenbachi rare

Bryozoa

23 Lichenalia concentrica; common in very irregular and much distorted masses.

Corals

24 Enterolasma caliculus common

Crinoids

25 Eucalyptocrinus; fragments of root stem and calyx.

In the lenses below Lewiston hights the same species except nos. 2, 3, 9, 10, 14, 15, 17 to 20 and 25 have been found. Rhynchotreta cuneata americana has more the features of the same species from the western Niagara than those of the Rochester shale species.

Spirifer crispus is commonly deficient in plications approaching in this respect and in the character of the sinus, S. eriensis from the Manlius limestone. Atrypa nodostriata is robust, convex, with coarse rounded plications and rather faint concentric striations, characters intermediate between A. reticularis of the Clinton and A. nodostriata of the Rochester shale. Besides these species and some not yet identified, the following occur.

Cephalopoda

26 Orthoceras annulatum

27 O. medullare (?) rare

28 O. sp.

Pelecypoda

29 Modiolopsis cf. subalatus?

The origin of these lenses is still obscure. Many of the fossils found in them are characteristic of the Niagara group of the west, but are rare or wanting in the Niagaran of New York. This is specially the case with the trilobites (Illaenus ioxus) and the cephalopoda. Dr E. N. S. Ringueberg many years ago studied these limestone masses as exposed at Lockport and other more eastern localities, and he termed them the "Niagara transition group".[1] He found in this rock 32 Niagara species, 11 species common to the Clinton and Niagara, two species found otherwise only in the Clinton, and two species not found outside of this rock. The origin and significance of these unique deposits are being carefully studied by the state paleontologist.

### Rochester shale

The Rochester (Niagara) shale has a total thickness of about 68 feet in the gorge of the Niagara. It is here divisible into a lower and an upper half. The lower portion is a highly fossiliferous shale with numerous limestone bands, and terminates in a series of thin calcareous beds with shaly partings in all about 4 feet thick, and extremely rich in bryozoa. The upper 34 feet are quite barren and have few limestone layers.

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[1] Am. nat. 1882. 6:711–15.

Plate 15

View of the New York bank a short distance north of the Devil's hole. The gorge-road is shown below, and the New York Central railroad cut near the middle. The fourth shanty is shown a short distance to the left (north) of the bridge.

**Lower shales.** The beds immediately succeeding the Clinton limestone are calcareous shales with frequent thin limestone layers. The latter are the most fossiliferous, being in general entirely made up of organic remains. The calcareous beds of the lower 5 or 10 feet are particularly rich in crinoid remains. Chief among these organisms, on account of its abundance and perfection, is the little triangular Stephanocrinus ornatus, which may be found in most of the calcareous layers. Fragments of Eucalyptocrinus are always common, while the characteristic Niagara cystoid Caryocrinus ornatus is also found, though not so abundantly as in the upper part of the lower division. The most abundant brachiopod of the lower shales is Whitfieldella nitida oblata, similar to the specimens found in the limestone lenses. The little Orthis, Dalmanella elegantula, is also common, ranging throughout the lower division of the shales. Spirifer niagarensis is common above the lowest 3 or 4 feet of the shale. Orthothetes subplanus, a large, subsemicircular and nearly flat brachiopod, is abundant in some of the calcareous layers, which at times seem to be composed of it, so thickly are these shells piled one on the other. Atrypa nodostriata is the commonest representative of the genus, the larger A. reticularis, so abundant in the upper Clinton, being comparatively rare and subordinate in development. In the limestone bands A. nodostriata is usually rotund, but in the shaly beds it is most commonly compressed. Trilobites are comparatively rare in these lower shales, though representatives of all the species found in this region have been obtained from them. Bivalve molluscan shells are also uncommon, but the gastropods, Diaphorostoma niagarense and Platyceras are not infrequent.

Some of the calcareous bands are almost barren of organic remains, but in most cases these beds will be found to constitute the chief repositories of the fossils.

*Bryozoa beds.* A short distance south of the third watchman's hut, the section comes to an end, being for some distance replaced by a soil-covered and more or less wooded bank. Where the section

ends the upper Clinton limestone is only a few feet above the road-bed, and the shale above it is accessible. 29 to 30 feet above the top of the limestone, a group of calcareous beds rich in bryozoa project from the bank, being readily traceable for some distance on account of their compact nature. Their total thickness is about 4 feet, and they consist of numerous thin limestone layers with shale partings of greater or less thickness. On the weathered surfaces of the limestone layers, the bryozoans stand out in relief, and such surfaces will often be found completely covered with these delicate organisms. The cylindric types prevail, but the frondose forms are also common. With them occur brachiopods and other organisms. Slabs of this rock are often found on the talus slopes, and they are among the most attractive objects that meet the collector's eye. The section begins again, after an interruption of perhaps a quarter of a mile, near the old quarry in the Clinton limestone. (Plate 15) Between the river and the railroad are several mounds of shale, which were left in place when the railroad cut was made. These are subject to disintegration, and the fossils in consequence weather out. They may be picked up on these mounds completely weathered out, and often in perfect condition. The best of these mounds is about halfway between the old Clinton limestone quarry and the fourth watchman's hut. Here the top of the mound is on the level of the top of the Bryozoa beds, the whole thickness of which is therefore included in this remaining mass. As these beds are extremely fossiliferous, this mound is a productive hunting ground.[1]

An equally productive locality for weathered-out fossils is the slope of disintegrated shale rising from the Rome, Watertown and Ogdensburg railroad tracks above Lewiston hights. The best hunting ground is in the little gullies made by the rivulets of rain water in the bank. Some glacial till is here mingled with the clay from the decomposed shales, and it requires a little attention to distinguish the two.

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[1] The fossils here obtained are extremely delicate and brittle. They should be placed at once on layers of cotton batting, in a small box and covered with similar material, the box being completely filled. This is the only way in which many of these delicate fossils can be carried away without breaking.

**Upper shales.** Above the Bryozoan beds the shale is soft, and more evenly and finely laminated, splitting often into thin slabs of moderate size. Hard calcareous beds are generally absent, though occasionally found near the top. The stratification and lamination is much more strongly marked in this than in any other division of this rock. When freshly broken, the shale has a brownish earthy color, which changes to grayish when the rock decomposes to clay. Fossils are rare, those found being seldom well preserved. In most cases the shells are dissolved away, leaving only the impressions of the fossil, which from compression become faint, and are not readily recognized without careful scrutiny. The most common remains found in these rocks are bivalve mollusks (pelecypods) and trilobites. Among the former Pterinaea emacerata is the most abundant, while Dalmanites limulurus is the chief among the trilobites of these beds. Other trilobites also occur in these shales, notably Homalonotus delphinocephalus, as well as a number of brachiopods.

Toward the top fossils become rarer, and finally are wanting altogether. The shale becomes more heavy bedded, and calcareous layers begin to increase. The last 10 feet or more are quite calcareous and compact, and have an irregular fracture. They grade upward into the basal layers of the Lockport (Niagara) limestone.

### Lockport (Niagara) limestone

The limestone which succeeds the Rochester or Niagara shales forms the summit rock of the series from the edge of the Niagara escarpment to south of the falls. It consists of a number of distinct strata, of varying characters, most of them very poor in organic remains. The total thickness exposed in the Niagara region is not over 130 feet, but borings show that the thickness of the limestone lying between the Rochester shale and the Salina shales is from 200 to nearly 250 feet. Some of the upper beds of this limestone mass may represent the Guelph dolomite and others may belong to the base of the Salina beds. Nevertheless we may confidently assume that the thickness of the Lockport limestone in this region, is at least 150 feet.

**Hydraulic cement beds.** 1) The lowest stratum of the series is a hard, compact, bluish gray silicious limestone, weathering whitish on the exposed faces, and breaking into numerous irregular fragments larger near the bottom of the stratum but becoming small, angular and subcubical near the top, where the weathering is similar to that obtaining in the upper parts of the shales. This stratum varies from 7 to 8 feet in thickness being in places divided into two tiers, the upper one, 4 feet thick, appearing as a distinct bed. This weathers to a creamy gray color, and breaks into small angular fragments with no regularity of fracture, and independent of the plane of stratification. On some of the weathered edges of this rock irregular stratification lines are visible, giving the beds the appearance of a fine grained sandstone. Occasionally small geoditic cavities occur lined with dolomite or gypsum. The line of contact between this stratum and the underlying shale is an irregular one, the shale surface having a wavy character.

2) This rock is succeeded by a 4 foot stratum of arenaceous limestone which shows no well marked stratification lines on the weathered surfaces, though in places a distinct cross-bedding structure appears. It peels off in irregular slabs parallel to the cross-section, i. e. at right angles to the stratification plane. Near the top of this stratum are a few thin beds which show the finer stratification structure on the weathered edges, the character of this structure being such as is found in fine grained sandstones.

Both these strata appear to be wholly destitute of fossils. It is not improbable however that the scattered geodes represent the places where corals or crinoids occurred, which have subsequently been altered or dissolved out. Aside from this, there is no evidence that this rock ever was fossiliferous, and it is most probable that it represents the accumulation of fine calcareous mud or sand.

**Crinoidal limestone.** 3) The compact hydraulic rock is abruptly succeeded by a stratum of highly crystalline limestone, on the weathered surfaces of which joints of crinoid stems and other organisms stand out in relief, particularly in the lower part of the stratum. The rock is entirely composed of fragments of organisms which were ground up and mingled together in great profusion. Oblique

bedding lines may be observed occasionally, indicating that the fragments were subject to wave action. The stratum varies in thickness from 5 to 6 feet, and is occasionally divided by horizontal sutures which show a marked stylolitic structure similar to that found in the crystalline upper Clinton limestone. The contact between this and the underlying stratum is wavy. This rock has been quarried at Lockport under the name of Lockport marble.

**Geodiferous limestones.** The crinoidal limestone is succeeded by strata all of which are more or less geodiferous, though varying considerably in composition and structure.

4) The rock immediately following on the crinoidal bed is a 4 foot stratum of compact, gray fossiliferous limestone, the fossils being of a fragmentary character. Stratification structure is well marked on the weathered surfaces, specially in some of the lower beds of the stratum. Sometimes there is only one thick bed, at others the stratum consists of a number of thin beds with a heavy one near the center. The thin beds show the stratification structure best, having at the same time a strongly granular character. As the fossils are fragmentary, and only accessible on the weathered surfaces, little is known of the organisms that constitute it. Crinoid joints occur, but they are less characteristic of this than of the lower stratum. Geodes however are not uncommon, the cavities being lined with crystals of pearl spar (dolomite) or filled with masses of snowy gypsum.

5) The fifth stratum of limestone in this series is a finely crystalline magnesian rock, like the others destitute of fossils except in so far as these are represented by geodes. The latter are common and filled with alabaster, or sometimes with massive or crystallized anhydrite. The latter is distinguished from the crystallized gypsum or selenite, which it closely resembles, and which occasionally occurs in the same beds, by the cleavage, which is rectangular and nearly equally perfect in three directions in anhydrite, while it is perfect in one direction only in the selenite.

6) A finely crystalline, somewhat concretionary dolomitic limestone, 3 feet thick, next succeeds, the weathered sectional surfaces of which, buff in color, show the fine stratification structure, which

is of the type of the cross-bedding structure in sandstone. Such structure indicates that the bed possessing it was a fine calcareous sand, subject to shifting movements by waves and deposited in moderately shallow water. We need look for organic remains in such a rock with no more assurance of finding them than we bring to the examination of uniform bedded shales. They may be abundant or they may be rare or absent altogether. Thus a limestone need not be necessarily a fossiliferous rock.

Geodes of the usual type are common, the dolomitic lining predominating.

7) On the preceding thin stratum follows a limestone mass of very uniform character, hardly separable into district strata, though consisting of numerous beds.[1] 27 feet of this stratum are shown at the quarry near the northern end of the section, where the upper exposed bed forms the surface rock of the plateau above. The beds are generally of considerable thickness, but the fine stratification structure is not so well marked as in the strata below. The rock may be considered a compact granular dolomite, in which considerable change has taken place since its original deposition. It is of a grayish color but weathers to a lighter tint. Geodes are plentiful, often quite large, and in these, minerals of great beauty are not infrequently found. The most common are the snowy variety of gypsum or alabaster, the darker gray, massive, fine anhydrite and the uniform, fine, dolomite rhombohedra with curved faces, generally of a pinkish tint and familiarly known as pearl spar. Long slender crystals of calcite, generally in the form known as scalenohedra, or dogtooth spar, are not uncommon. These are commonly of a golden color, and large enough to show well their crystal faces. In the new power tunnel which was excavated in the neighborhood of the falls, large masses of transparent gypsum of the selenite variety were found in cavities in this rock. Some of these pieces were 6 inches in length. Masses of limestone lined with pinkish dolomite crystals and occasional large masses of silvery selenite, and set with

[1]The distinction between stratum and bed is an important one. A stratum is a rock mass having throughout the same lithic character, and may be thick or thin. A bed, on the other hand, is that portion of a stratum limited by horizontal separation planes. *See* Geology and paleontology of Eighteen Mile creek pt 1. Introduction.

amber crystals of calcite, were also found in these cavities, the combination being such as to produce specimens of great beauty. Among the rarer minerals found in this rock is the crystallized and cleavable anhydrite, which like gypsum is a sulfate of calcium, but without the water which is characteristic of that mineral. Anhydrite crystallizes in the orthorhombic system, and its cleavage is in three directions, at right angles to each other (pinacoidal), thus yielding rectangular fragments and enabling one to distinguish it from selenite with little difficulty. It is also a trifle harder than selenite which is easily scratched with the finger nail. This form of anhydrite is rather rare, the principal localities for it being foreign. Masses of considerable size have been found in the limestone of this quarry, and small pieces are not uncommon in the geodes of these strata. Both selenite and the cleavable anhydrite are commonly called "mica" by the uninitiated; that mineral however does not occur at Niagara. Small masses of fibrous gypsum or satin spar have been found, but these are very rare. The satin spar of which the cheap jewelry sold in the curiosity shops is made is not from Niagara.

Among the metallic minerals found in this rock, zinc blende or sphalerite is most common. It is generally of a yellowish or light brownish color and brilliant resinous luster. Large masses however are rare. Galenite or lead sulfid crystals are also occasionally found, but this mineral is comparatively rare. In addition to these, iron pyrite, iron-copper pyrite (chalcopyrite), green copper carbonate (malachite), fluor spar (fluorite), iron carbonate or brown spar (siderite, generally ferruginous dolomite), strontium sulfate (celestite) and native sulfur as well as other minerals are met with.

The total thickness of the limestone exposed in this section is thus somewhat more than 55 feet. At Lewiston hights, on the edge of the escarpment, only about 20 feet are exposed. This includes the two lower strata of hydraulic limestone, the crinoidal limestone and a few feet of the lowest geodiferous beds (stratum 4). Over this lie some two or three feet of glacial till. The distance between the edge of the escarpment and the quarry at the end of the section is a little over a mile and a half, the increase in thickness of the

limestone and the rate of dip (since the surface is about level) is therefore a trifle less than 25 feet in the mile.

The crinoidal limestone is the most prominent stratum on the edge of the escarpment. From its base springs of cold and clear water issue at numerous places along the outcrops, both on the edge of the escarpment and in the gorge. The most prominent of these is at the head of " Milk cave " or St Patrick's falls, and here as almost everywhere at the base of the crinoidal limestone, shallow caverns abound. One of these caverns near the head of the falls, has a depth of 35 or 40 feet and is high enough to permit one to walk upright. No stalactites are found in these caverns, but the walls are much disintegrated and in places covered with a fine residual sand.

In the fields above this cavern are several sink holes of moderate depth, which serve as catchment basins for the waters of the surrounding country, which issue from these caverns during the wet seasons.

The cavern known as the Devil's hole belongs to this category. As in the other caverns, the roof is formed by the crystalline crinoidal limestone (stratum 3), the cavern itself being hollowed out in the hydraulic cement rock. This cavern is deeper than most others, and at the end a spring of deliciously cool water issues from between the two beds, the upper " spring line " of this region. There is no evidence that the cavern extended any deeper than it does at present, nevertheless the spot is worth visiting, as it is the only accessible one of the numerous springs and caverns. The fall of the Bloody run at this place is over a thickness of almost 60 feet of limestone, and the chasm which this stream has worn is interesting both from its historic and scenic points of view.[1]

West of the Niagara river on Queenston hights several quarries have been opened in these limestones, some distance south of the edge of the escarpment. The rock quarried is the crinoidal limestone and overlying beds. The total depth of rock in the quarry is 27 feet, of which the lower 14 or 15 feet are bluish gray and the upper of a lighter gray color. The limestone is here much more uniform, crystalline throughout and more fossiliferous. This may

[1]*See* brief mention of Bloody run massacre in Introduction.

indicate a nearness to the reef of growing organisms which supplied the material for these beds. Geodes lined with dolomite crystals occur in this rock, though not so plentifully as at the quarry in the gorge. Below the crystalline limestone is found the cement rock, which is from 4 to 10 feet thick and is quarried in a tunnel under the limestone quarry.

Owing to the resistant character, the limestone is everywhere exposed in the gorge, forming cliffs which are almost invariably perpendicular. Large blocks of this rock cover the talus everywhere, one of the largest of these being "Giant rock" along the gorge road. This is a block of the upper geodiferous limestone which has fallen from above, and now lies with its stratification planes at an angle of about 45°.

The limestones are well exposed along the gorge road, south of the railroad bridges, but without a special permit no one is allowed to walk on this roadbed. The contact between the limestone and the shale is here very irregular, indications of erosion of the shale prior to the deposition of the limestone occurring. The limestone is also somewhat concretionary, rounded masses projecting down into the shales. The succession of strata is here as follows:

1 Concretionary, irregularly bedded gypsiferous limestone, often earthy and with occasional thin, shaly layers; it splits readily into slabs perpendicular to the stratification. Thickness 6-8 feet.

2 Fine grained limestone with sandy feel, sometimes massive, sometimes in shattered layers with earthy or shaly partings, and separated from the underlying rock by an earthy layer. It weathers to an ashy or sometimes an ochery color, and varies somewhat in thickness. The upper layer is however a solid and fine grained limestone. Thickness 4-4.5 feet.

Strata 1 and 2 are the equivalent of the cement beds.

3 Crystalline and crinoidal limestone abruptly succeeding the lower bed. It is massive though somewhat thin bedded and contains geoditic cavities filled with gypsum. This continues uniform for a thickness of about 19 feet.

4 Compact limestone; concretionary with cavities containing gypsum and other minerals, and with sphalerite embedded in the rock.

The bedding and upper contact lines are irregular. Thickness 14-15 feet.

5 Compact, finely crystalline and homogeneous dolomitic rock, showing traces of fossils and slickensides. Beds showing Stromatopora common. In places the rock has a porous appearance and is rich in geoditic cavities, which are lined with dolomite and calcite crystals. Thickness 19 feet.

This stratum forms the lower portion of the cliff at the first cut on the gorge road, and the basal part of the mass left standing on the river side. Heads of Stromatopora may be seen in this rock, some of the geoditic cavities having replaced this fossil. This is about the summit of the beds exposed in the quarry at the end ot the railroad section.

6 Earthy, compact dolomite in thin layers, which give the cliff the appearance of a stone wall. Toward the top the rock becomes more compact and heavy bedded, this giving the appearance of an overlying stratum. This rock is full of geodes lined with pearl spar or dolomite, the cavities ranging in size up to that of a fist or larger. The beds are generally less than a foot in thickness, the average being from 3 to 6 inches. Toward the top of the cut, the rock becomes more compact and finely crystalline, but otherwise remains similar. Pearl spar geodes remain common to the top. The thickness of this mass, at the beginning of the gorge road, is about 45 feet.

The total thickness of the limestone exposed on the gorge road is in the neighborhood of 110 feet. This is double the thickness found at the quarry, the distance between the two points in a straight line being about three miles or nearly four following the curvature of the river. The rate of increase in thickness, or the amount of dip of the strata is therefore about 20 feet to the mile.

Almost the only recognizable fossils found in these limestones, excepting the crinoid fragments, are the hydro-coralline Stromatopora (concentrica Hall) and the coral Favosites. Both occur in the middle and upper portions of the exposed mass, and may generally be seen in the weathered upper surfaces of the limestone beds. Thus wherever these beds are exposed on the sur-

face, as at the whirlpool on the Canadian side, at the fall of Muddy brook, and near Clifton, these fossils are generally weathered out in relief. They are however not readily separated from the rock. Many of the geodes still show traces of coral structure, which is sometimes shown in the included gypsum.

The limestone is well exposed in the cliff at Goat island, where it has a total thickness of about 110 feet. The contact between the shale and limestone can be seen near the entrance to the Cave of the Winds, where it is about a foot above the top of the stairs. The roof of the Cave of the Winds is formed by the crystalline crinoidal limestone, the same bed which forms the roofs of all the minor caverns along the gorge. The cement beds, about 10 feet thick, together with the 70 feet of Rochester shale, are removed by the spray to a depth of perhaps 30 or 40 feet, the floor of the cave being probably on the upper Clinton limestone, thus making the hight of the cavern 80 feet. Floored and roofed by resisting beds of crystalline limestone, this great cavern is a fit illustration of selective erosion by falling water on rocks of unequal hardness.

The massive limestone which forms the vertical cliff of Goat island is 68 feet thick, its base being on a level with the foot of the Biddle stairway. The top of this cliff marks approximately the level of the falls on either side of Goat island, which therefore have a total thickness of nearly 80 feet of limestone, of which however the lowest 10 feet yield to erosion as does the underlying shale. We may thus say that at the falls there are 70 feet of resistant limestone on top, and 80 feet of yielding shales and limestones below. As the crest of the falls approximates 160 feet above the river below, at least 10 feet of Clinton limestone are found above the water level.

From the top of the vertical cliff at Goat island a sloping bank exposing thin bedded limestones, overlaid by about 10 feet of shell-bearing gravels, rises to a hight of about 40 feet, while on either side of Goat island these thin bedded limestones form the rapids above the two falls. As the total hight of the rapids is about 50 feet, and, as they are formed along the strike of the beds owing to the right-angled turn in the river at this point, the thickness to be added to the known limestone mass is not over 50 feet, giving a total thickness of 130 feet of limestone exposed within this region.

### Guelph dolomite

This rock, named from its occurrence at Guelph (Ont.) about 75 miles northwest of Niagara falls, is, so far as known, absent from the Niagara district. As before noted, it may however be represented in the buried hundred feet of limestone (more or less) which lie above the 130 feet of known rock, as shown by the borings in this region.

### Salina beds

The basal beds of the Upper Siluric are the saliferous shales and calcareous beds of the Salina stage, so named from the salt-producing village of Salina in Onondaga county. This is the horizon which furnishes all the salt, as well as the gypsum of New York state and the adjoining territory. In the Niagara region this formation is not well exposed, owing to the soft character of the rock which has permitted deep erosion in preglacial times, and to the extensive drift deposits which cover it. The only known exposures on the Niagara are on Grand island and on the Canadian side of the river opposite North Buffalo. On Grand island the Salina rocks may be seen at Edgewater about 200 yards below the boat landing. Here the following section is exposed.[1]

3 Light colored, soft, friable gypseous shales, 5 feet
2 Greenish shales containing nodules of gypsum, 1½ feet
1 Black shale in the river bed

The exposure extends 300 yards down the river bank.

At the extreme northern end of the island, where it divides the river, an impure, thin bedded limestone of this series is exposed. The exposures on the Canadian bank begin a short distance south of this, and extend to the International bridge, the rock here being a more or less gypsiferous shale.

From the numerous borings in this region we have however gained a fair knowledge of the character and thickness of this rock, the latter averaging, according to Bishop, 386 feet. The best available record of the rocks lying between the Waterlime and the Niagara series of limestones is the core of a well drilled on the land of the Buffalo cement co. in North Buffalo. This core, which has a

[1]Bishop. 15th an. rep't N. Y. state geologist. 1895. p. 311.

length of 1305 feet, is now preserved in the museum of the Buffalo society of natural sciences, and from it the following succession of strata can be demonstrated.[1]

| | | Feet |
|---|---|---|
| Rondout waterlime | Waterlime above the mouth of the well, about | 7 |
| | Shale and cement rock in thin streaks | 25 |
| | Tolerably pure cement rock | 5 |
| | Shale and cement rock in thin streaks | 13 |
| Salina | Pure white gypsum | 4 |
| | Shale | 2 |
| | White gypsum | 12 |
| | Shale | 1 |
| | White gypsum | 4 |
| | Shale and gypsum mottled | 7 |
| | Drab colored shale with several thin layers of white gypsum | 58 |
| | Dark colored limestone | 2 |
| | Shale and limestone | 4 |
| | Compact shale | 3 |
| | Gypsum and shale mottled and in streaks approximating | 290± |

The gypsum of this formation has never been mined in this district, owing to the strong flow of water through these strata. No salt beds are found in the Salina of this region, though they are characteristic of the formation farther east. Salt water is however obtained. Fossils are very rare throughout these beds; none have been found in the exposures on the Niagara river.

### Rondout waterlime

The Salina beds of this region grade upward into a magnesian limestone which contains a considerable amount of aluminium silicate. The upper portion of this series, which in the Niagara region has a thickness of about 50 feet, is very uniform in character and suitable for the manufacture of hydraulic cement. In North Buffalo, extensive quarries have been opened in this rock by the Buffalo

[1] Pohlman. Cement and gypsum deposits in Buffalo. Am. inst. min. eng. Trans. Oct. 1888.

cement co., and here a stratum nearly 6 feet thick is quarried and converted into cement. As the quarries are opened south of the second escarpment (inface of the Onondaga cuesta[1]), the surface rock of Onondaga limestone and the Manlius limestone have to be stripped off before the cement rock is reached.

The characters of the several strata have been briefly enumerated in the section derived from the gas well core. The upper beds, which are alone accessible in this region, may generally be seen in the escarpment, specially where it is crossed by streams, as at Williamsville, or where quarries have been opened. The rock is fine grained, often showing a marked banding or lamination, and breaks with a conchoidal fracture, producing rounded surfaces.

In this rock we find entombed the remains of those remarkable crustacea, the Eurypterids, whose bizarre form, remotely fish-like, has excited more interest than any other fossil found in this region. These Crustacea have made the Waterlime of Buffalo famous, and the Buffalo society of natural sciences, whose collections embrace a magnificent series of these fossils, has fittingly adopted it as chief among its insignia.

Besides these crustacea several other organisms have been found in the Waterlime strata of north Buffalo. Among these are a number of undescribed brachiopods, including at least one species of Lingula.

## Manlius limestone

The waterlime of north Buffalo is succeeded by a stratum of impure limestone from 7 to 8 feet in thickness and known locally by the name of "bullhead" rock. The line of demarkation between the two formations is not a very pronounced one, for the inferior rock grades upward into the superior one. The rock is a dolomitic limestone of a very compact semicrystalline character, with a high percent of argillaceous material, and not infrequently a strong petroleum odor. It is mottled, having frequently the appearance of a limestone breccia, and consists of purplish gray, angular or rectangular pieces and similar light colored and more yellowish ones. The latter appear to be more argillaceous than the former. There

[1] *See* chapter I.

is no conclusive evidence that the rock is brecciated, nevertheless the coloration strongly suggests it.

This rock is commonly very porous in its upper portion, the cavities being often lined with crystals of calcite or other minerals. The smaller of the cavities are due to the dissolving out of the small coral, *Cyathophyllum hydraulicum*, which was exceedingly abundant in the upper part of the stratum. This coral is generally found in a prostrate position, with the mold perfectly preserved in the inclosing rock matrix, so that a perfect cast of the coral can be obtained by the use of gutta percha or dentist's wax. The best exposure of this rock is in the walls of the quarries of the Buffalo cement co. It may also be seen in the face of the Onondaga escarpment at Williamsville and eastward. In many places in the cement quarries, the upper part of this limestone is rich in iron pyrites, which commonly occurs in small cubes, not infrequently oxidized to limonite. Green stains of hydrous carbonate of copper, or malachite, are not uncommon, these resulting probably from the decomposition of chalcopyrite, which is disseminated in minute grains through portions of the rock. Many of the geode cavities contain scalenohedra or acute rhombohedra of calcite, as well as sulfate of strontian.

A remarkable feature of the Manlius limestone of the Niagara region is the nature of the fossil fauna which it contains. This fauna shows an intimate relation to the Coralline limestone fauna of Schoharie county (N. Y.) a rock which is regarded the eastern equivalent of the Lockport (Niagara) limestone of this region. Several of the species found in the Manlius limestone of this region are identical with those of the Coralline limestone, while between other representative species of the two formations there exists a very close relationship. It is difficult to escape the conclusion that the Manlius limestone fauna of the Niagara region is a late return of the Coralline limestone fauna, at the close of the long interval during which the Salina shales were deposited in the Siluric seas of this region.

### The Siluro-Devonic contact

The Manlius limestone of the Niagara region is succeeded by the Onondaga limestone of Devonic age. The latter rests unconform-

ably on the former, this unconformity being emphasized by the absence of all Lower Devonic strata in this region, with the exception of thin lenses of sandstone which may be correlated with the Oriskany. The upper surface of the Manlius limestone is knotty and concretionary, producing minor irregularities, but in addition to these there are well marked traces of the erosion of these strata, prior to the deposition of the overlying beds. These traces are of the nature of channels and irregular truncations of the strata, the former in some cases assuming considerable importance. (Fig. 21-23)

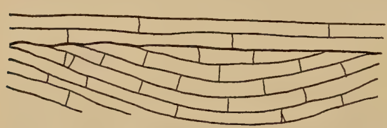

Fig. 21 Unconformable contact between Manlius and Onondaga limestones, Buffalo cement quarry.

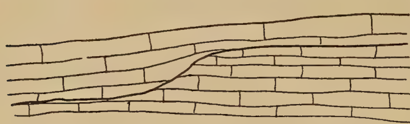

Fig. 22 Erosion of Manlius limestone prior to deposition of Onondaga limestone, Buffalo cement quarry.

In the east wall of the quarry, not far from the stamp mill, the surface of the Manlius limestone is strongly excavated, the excavation being mainly filled by beds of the Onondaga limestone. Between the two limestones occurs a mass of shale and conglomerate having a total thickness, in the central portion, of something over a foot. The lower 6 or 8 inches are a limestone conglomerate, the pebbles of which are fragments of the underlying limestones. These pebbles are flat, but well rounded on the margins, showing evidence of protracted wear. They are firmly embedded in a matrix of indurated quartz sand, which surrounds them and fills in all the interstices. This bed thins out toward the sides of the channel. On the conglomerate lie about 6 inches of shale and shaly limestone, and these are succeeded by the Onondaga limestone. The width of the channel, which is clearly an erosion channel, is about 18 feet, and its depth is about 3½ feet. (Fig. 23)

From the point where this channel is seen, the contact can be traced continuously for a thousand feet or more eastward, along the quarry wall. It frequently shows a thin shaly bed, often containing quartz grains, lying between the two limestones.

Not very far from the channel just described, a remarkable "sandstone dike" penetrates the Siluric limestones of the quarry wall.

This dike, which can be clearly traced in the wall of the quarry for a distance of perhaps 30 feet in an east and west direction, was

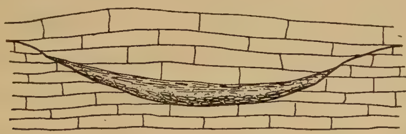

Fig. 23 Channel in Manlius limestone with Oriskany sandstone and conglomerate layers, capped by Onondaga limestone, Buffalo cement quarry.

caused by the filling of an ancient fissure in the Siluric strata, by sands forcibly injected from above. The fissure had a total depth of about 10 feet; its walls were very irregular, and at intervals lateral fissures extended in both directions. (*See* Fig. 24) All of these are now filled with pure quartz sand, firmly united into a quartzose sandstone by the deposition of additional silica in the interstices between the sand grains.

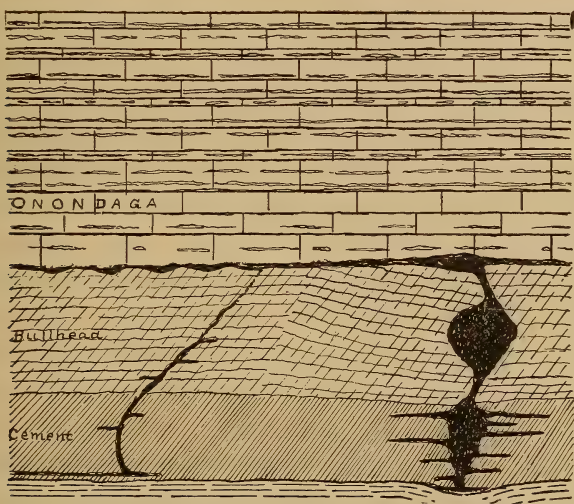


Fig. 24 Sandstone dike in the Siluric strata of the Buffalo cement quarries. (After Clarke)

The dike penetrates the "bullhead" rock and enters the waterlime to a depth of from 2 to 3 feet. It is squarely cut off at the top, where the Onondaga limestone rests on its truncated end and on the limestone flanking it. The Onondaga limestone is entirely unaffected by the dike, being evidently deposited after the formation and truncation of this remarkable mass of sandstone. The width of

the filled fissure is scarcely anywhere over 2 feet, but the lateral offshoots extend many feet into the walls of Manlius limestone. These offshoots or rootlets of the dike are irregular, commonly narrow, and often appear as isolated quartz masses in the Manlius or the waterlime rock, the connection with the main dike not being always discernible. Such masses of quartz sandstone have been traced for more than 30 feet from the dike. The irregularity of the walls of the fissure is very pronounced. Angular masses of limestone project into the quartz rock, while narrow tongues of sandstone everywhere enter the limestone. Extensive brecciation of the limestone has occurred along the margin, and the sandstone there is filled with angular fragments of the limestone, which show no traces of solution or wear by running water. These limestone fragments are themselves frequently injected with tongues of the quartz sand. Microscopic examination shows evidence of a certain amount of shearing along the margin of the dike, accompanied by a pulverizing or trituration of the limestone, and followed by reconsolidation. These and other features point to a cataclysmic origin of the fissure which contains the dike and a more or less violent injection of the sand. The fissure must have been formed and filled before the deposition of the Onondaga limestone and while the Manlius limestone was covered by a stratum of unconsolidated sand. The formation of the fissure and the injection of the sand into it from above must have occurred simultaneously; for this appears the only way to account for the inclusion of large fragments, or "horses", of the wall rock in the loose sand, and the injection of the sand into all the cracks and crevices. It seems probable that the fissure records an earthquake shock during the period intervening between the close of the Siluric age and the deposition of the Devonic limestones. This is borne out by the occurrence of numerous small faults or displacements in the underlying strata of waterlime.

### Devonic strata

The Lower Devonic is represented in the Niagara region by the thin beds of shale and sandstone before mentioned as occupying erosion hollows in the Manlius limestone. These are perhaps the

equivalent of the Oriskany sandstone of eastern New York, though no fossils have been found in them. With the exception of these layers the Lower Devonic strata are wanting in this region.

The Middle Devonic is however well represented in the Niagara region by the Onondaga limestone. This rock, which, as has been shown, rests in most cases directly on the Manlius limestone, consists of a lower crystalline and highly fossiliferous portion, and an upper mass full of layers of hornstone or chert which on weathered surfaces stand out in relief. This part of the formation is generally known as the Corniferous limestone, in reference to the layers of chert which make the rock unfit for other use than rough building. Owing to the presence of the hornstone, this rock effectually resists the attacks of the atmosphere, and hence its line of outcrop is generally marked by a prominent topographic relief feature, the second escarpment of western New York i. e. the inface of the Onondaga cuesta.

The chert-free lower member of this formation varies greatly in thickness even within a limited territory. It is in places extremely rich in corals, and outcrops of this rock show all the characteristics of an ancient coral reef.

### History of the Niagara region during Siluric time

We have now gathered data for a brief synopsis of the history of this region during Siluric time. Much still remains to be learned, but from what is known we can trace at least in outline the sequence of geologic events which characterized that ancient era of the earth's history in this vicinity.

When the Siluric era opened, New York, with portions of Pennsylvania and southern Ontario, was covered by the shallow Medina sea. This sea appears to have been of the nature of a mediterranean body of water, which later changed to a bay opening toward the southwest. This "Bay of New York", as we shall call it, came into existence by the orogenic disturbances which marked the transition from the Ordovicic to the Siluric era, and as a result of which the Taconic mountain range, with the Green mountains and the corresponding Canadian ranges, were elevated. This cut off the

communication between the open Atlantic and the interior Paleozoic sea which existed during Ordovicic time. This bay was thus surrounded by old-lands on the north, east and southeast, and its waters appear to have been very shallow. We do not know just what the conditions were under which the early Siluric deposits of this region were made; for the lower beds are so barren of organic remains, that we are forced to look for evidences other than that furnished by fossils, of the physical conditions during this period. It is not improbable that the waters of the early Medina sea were cut off from the ocean at large, at least sufficiently to prevent a free communication. This may not have been the case at first; for Arthrophycus harlani flourished in these waters during the deposition of the Oswego beds,[1] and this species characterizes the rocks of late Medina age, during the deposition of which we have reason to suppose that a junction of the Medina sea with the ocean at large had been effected.

Along the eastern and southeastern margin of this interior water body were deposited the thick beds of conglomerate, which now constitute the capping rock of the Shawangunk and other ranges of hills, while farther west, at a distance from the source of supply, the Oswego sandstone was accumulating. Later the character of the deposit changed in this region, from the gray silicious sands to the impalpable muds and fine sands of the lower Medina. Whatever the source of these sands, ferruginous matter was plentiful, as shown by the red color of the deposits, and this leads to the supposition that they were derived from the crystalline rocks of the Adirondacks and the Canadian highlands and not from Ordovicic or Cambric deposits.

It is not improbable that, during the early Medina epoch, the waters of this basin were of a highly saline character. No deposits of salt were formed, or if these existed, they were subsequently leached out. The Medina beds are however rich in saline waters, salt springs being common throughout this region,[2] and this may

[1] This species is found in the eastern part of the district, at the base of the Oneida conglomerate.

[2] In the early part of the century salt was not infrequently manufactured from these springs.

indicate a high degree of salinity of the waters of the early Medina sea. If such was the case, it may have been accompanied by a more or less arid climate, which favored the concentration of the sea water. Thick beds of terrigenous material accumulated in the center of the Medina basin reaching in the Niagara region a thickness of over a thousand feet. These early deposits probably did not extend far west for, though in northern Ohio and Michigan, Medina beds from 50 to 100 feet or more in thickness are known, these are probably to be correlated with the upper Medina of the Niagara region.

Toward the close of the Medina epoch, the Siluric sea had encroached on the lands to such an extent as to effect a junction with the Medina basin, whereupon normal marine conditions were again established. This is indicated by the marine fauna and flora which characterize the upper Medina beds. The first deposit in this region, on the reestablishment of normal marine conditions, was the white quartzose sandstone which caps the red shale of the lower series. Mud and sand now alternated, indicating an oscillation of conditions with numerous changes in the currents which distributed the detrital material. Thin beds of limestones also formed at rare intervals, chiefly from the growth of bryozoans in favorable localities. In the Bay of New York the waters continued moderately shallow, as shown by the well developed cross-bedding structure in the sandstones. At intervals large tracts seem to have been laid bare on the retreat of the tide, as indicated by the wave marks and other shore features which give the surfaces of some Medina sandstone slabs such a remarkable resemblance to a modern sand beach exposed by the ebbing tide. In fact, we may not inaptly compare this stage of the Siluric bay of New York with the upper end of the modern bay of Fundy, where the red sands and muds are laid bare for miles on the retreat of the tide.

After the last sandstone bed of the Medina stage had been deposited, the water probably became purer and deeper, and the 6 feet of Clinton shales were laid down in the Niagara region. In the eastern part of the Bay of New York, sandstones were deposited even during the Clinton epoch, while the conditions favoring the deposition of limestone existed only during the short interval in

the Niagara period, when the Coralline limestone of Schoharie was laid down. Westward, however, the adjustment of conditions went on more rapidly, and the Clinton limestones, with the calcareous shales and limestones of the upper Niagaran, became the characteristic deposits. During nearly the entire Niagara period life was abundant in the Siluric sea, and the Bay of New York had its marvelous succession of faunas, which have made these strata the standard for the Siluric beds of this continent.

All the Siluric limestones of the Niagara section show characters pointing to a fragmental origin, and in this respect they contrast strongly with the Devonic limestones in the southern part of the district. The latter, as before mentioned, show the characteristics of an ancient coral reef, and we may therefore assume that they were built up in situ by the polyps and other lime-secreting organisms. Not so with the Siluric limestones. These, to be sure, were derived from similar deposits by lime-secreting organisms, but these deposits were originally made in a different place from that in which we find the limestones today. A sedimentary limestone or lime-sandstone is similar to a quartz sandstone or a shale, in that the material of which it is formed is the product of erosion of preexisting rocks. In the case of the quartz sandstone, this is generally an inorganically formed rock, while the sedimentary limestones are most usually derived from organically formed rocks. In the former case, the source of the material is often a distant one, while in the latter it is generally, though not necessarily always, close at hand. A coral reef growing in moderately shallow water is attacked by the waves, as are all rocks which come within their reach. Erosion results, and the product of this activity is carried away and deposited on the ocean floor as a calcareous sand. Thus stratified deposits of limestones are formed, whereas in the original organic reef, no stratification is to be expected. In the immediate neighborhood of the growing reef, the beds of calcareous sand will slowly envelop the original deposit from which they were derived, and thus the source of supply is chiefly the upper growing portion of the reef. On the lime-sandstone strata which flank the reef, independent masses of coral may at times grow, while other or-

ganisms, such as mollusks and brachiopods, will also find this a convenient resting place. Thus the organically formed limestone masses and the fragmental limestones will interlock and overlap each other around the borders of a growing reef. It follows then that in the neighborhood of the growing coral masses the sands derived from their destruction will be coarser, the finer material being carried farther out to sea, and deposited at a distance from the source. Thus an approximate criterion for the determination of the distance of any given bed of calcareous sand from its place of origin is furnished. If deposits of such calcareous sand are made in shallow water, cross-bedding and ripple marks will be found just as in the quartz sands, and, as we have seen, the former structure is characteristic of most of the strata of Lockport limestone exposed in the gorge section at Niagara. It may be added that, as the organic limestone will continue to form as long as the conditions are favorable, the supply of calcareous sand is practically inexhaustible. Hence thick beds of such lime-sandstones may form.

In the Niagaran seas the chief reef-building corals were *Favosites*, *Halysites* and *Heliolites*, together with the hydro-coralline *Stromatopora*. Bryozoans also added largely to the supply of organically formed limestone of the various reefs. But perhaps the most important contributors in this connection were the crinoids and related organisms, which may at times have constituted reefs of their own. Their abundance is testified to by the frequent thick beds of limestone, which are almost wholly made up of broken and worn crinoid fragments. The crinoids fell an easy prey to the waves, for, on the death of the animal, the calyx, arms and stem would quickly fall apart into their component sections, and hence yield fragments readily transported by the waves. In the case of the corals and the shells, which latter probably formed no unimportant part of the organic contributions to the reefs, the work of grinding the solid limestone masses into a sand probably required the aid of tools, such as large blocks that could be rolled about by the waves, or it may have been aided by the omnipresent reef-destroying organisms.

The infrequency of exposure of the fossil reefs, which furnished the calcareous sand, need not disturb us. We must remember that

the actually exposed sections of these limestone strata are very few when compared with the great extent of the beds themselves. It must also be borne in mind, that vast portions of these limestone beds have been removed by erosion during the long post-Siluric time. When we realize that the actual reefs must have been widely scattered in the Niagara sea, and that our sections through these strata are random sections, we need feel no surprise at the unsatisfactory character of these exposures. It must however be added that sections farther east, as at Lockport or other localities, generally show much more of the reef character of the deposit, the corals in these being correspondingly abundant. The upper geodiferous beds of the limestone at Niagara were probably much more fossiliferous than the lower. As before mentioned, the geode cavities most likely are the result of alteration or solution of some fossil body, probably a coral. Though fossils may have been plentiful, none of these beds, so far as examined, show the characteristics of true reefs. They have more the aspect of beds of coral sand, on which isolated heads of corals and other organisms grew rather plentifully.

During the dolomitization of these limestone beds, which was probably brought about by chemical substitution before the consolidation of the coral sand, many of the fossils which were included in these sands probably suffered alteration and more or less complete destruction. Thus it will be seen that even the few organisms which were embedded in these coral sands, did not survive the subsequent changes, and thus the barrenness of these great limestone masses appears to be fully accounted for. The fossiliferous character of the upper Clinton limestone, as well as the coarseness of the calcareous fragments of which it is composed, points to a nearness of this rock to the source of the material; for in the vicinity of the coral and crinoid reefs the food supply for other organisms would be most abundant, and hence these would develop most prolifically in such a neighborhood.

A careful comparative study of the Niagaran deposits of New York and those of the middle states has brought out some important and interesting facts. These may be summed up in the

statement, that the New York fauna is more individualized, showing characteristics stamping it in some degree as a provincial fauna. The Niagaran fauna of the central states however is more closely allied to the European Mid-Siluric fauna than to that of New York state, from which we may conclude that the pathway of communication between the American and European Siluric seas was not by way of New York, a conclusion which is in entire harmony with those derived from the physical development of this region and the characteristics of the strata.

Weller[1] has collected data which indicate that the pathway of migration of faunas between the two continents was by way of the arctic region. According to Weller's interpretation of the facts, there existed in North America during Siluric time ". . . a north polar sea with a great tongue stretching southward through Hudson bay to about latitude 33°. There were doubtless islands standing above sealevel within this great epicontinental sea; and at the latitude of New York there was a bay reaching to the eastward, in which the Siluric sediments of the New York system were deposited. Labrador, Greenland and Scandinavia were in a measure joined into one great land area, though perhaps with its continuity broken, with a sea shelf lying to the north of it and another to the south. Another epicontinental tongue of this northern sea extended south into Europe, bending to the west around the southern part of the Scandinavian land and connecting with a Silurian Atlantic ocean. The sea shelf to the north of the Labrador-Scandinavian land was a means of intercommunication between northern Europe and the interior of North America, and the sea shelf to the south of this land was a pathway between England and eastern Canada." That portion of North America lying to the west of a line drawn from the Mississippi to the Mackenzie appears to have been dry land during the Niagara period, and connected with the Appalachian land on the east by the westward trending axis of the latter in the southern United States.

At the close of the Niagara period, there appears to have been an elevation of the continent which converted the Bay of New York

[1] Nat. hist. sur. Chicago acad. sci. bul. 4 and Jour. geol. 4:692-703.

and the greater part of the interior Siluric sea into a vast partially or entirely inclosed basin. This elevation appears to have been accompanied by climatic desiccation which brought about a rapid evaporation of the waters and a consequent increase in salinity. Thus this great interior water body was changed from a richly peopled mediterranean, to a lifeless body of intensely saline water, a veritable Dead sea. As the concentration of the brine continued, deposition of gypsum began, and later on the extensive beds of rock salt of this formation were laid down. Some of these salt beds in Michigan are reported to be a thousand feet thick, but none of the New York beds approach this thickness. The clastic strata of the Salina series were probably derived from the destruction of the sediments which were formed during the early periods of the Siluric and during preceding periods. This would account for the presence of limestone beds in deposits formed in a lifeless sea. All these limestones were more or less mixed with clayey sediments; they may in fact be regarded as consolidated argillo-calcareous muds derived from older limestones and shales. This is the character of the Waterlime and Manlius limestone which succeed the Salina beds, and which, though fossiliferous, could have no other source of origin than preexisting limestone beds.

The Waterlime has been regarded as a fresh-water formation. It is more likely however that it represents a return of marine conditions through the opening of channels between this interior basin and the ocean at large. This is indicated by the fauna, which includes undoubted marine forms. Whether this connection was through the old northern channel, or whether a new channel toward the east was opened is not apparent. The former is indicated by the character of the Manlius limestone which succeeds the Waterlime, and which in the Niagara region has features associating it with the corresponding deposits of Ohio, Michigan and Ontario, rather than its eastern equivalents. Whatever the nature of the transgression of the sea which took place in the late Siluric, it was not of long duration. The epoch of the Manlius limestone and with it the Siluric era were brought to a close with the withdrawal of all the waters from this portion of the continent, which thereafter for

a long period of time remained above the sea. During this time, the Helderbergian and other Lower Devonic strata were deposited in the Appalachian region, which by that time had established a southern connection with the open Atlantic.

Finally, toward the middle of the Devonic era, the sea once more transgressed on the abandoned continent, and again all this region was covered by oceanic waters. On the land surface of early Devonic times, now grew corals in great luxuriance; and reefs of great extent, with their accompanying deposits of coral sands, and their wealth of new life, again characterized the interior Paleozoic sea. It was not till long ages after, that this portion of the continent was again raised above the sea. This last elevation, which took place toward the close of Paleozoic time, was a permanent one, with the exception of a possible slight resubmergence of some parts of this region after the close of the glacial period. With the last great emergence of the land were inaugurated those long cycles of erosion outlined in chapter 1, which resulted in the formation of the great topographic features of this region, and which came to a close only with the envelopment of this region in the snow and ice of the great glacial winter.

*Chapter 4*

# FOSSILS OF THE NIAGARA REGION[1]

## PLANTS

The Paleozoic marine plants or seaweeds are generally classed together as " fucoids ", a term denoting a relation of these organisms to the modern rockweed, Fucus, which fringes the rocks of our seacoast. These plants were probably algae, but it is impossible in most cases to make a more precise classification. The condition in which these remains are found today—as a rule mere impressions or casts of the original—generally renders the determination of their affinities a hopeless task. In some remains the plant nature of the organism is even questionable.

### Genus BYTHOTREPHIS Hall

[Ety.: βυθοτρεφής, growing in the deep]

(1847. *Pal. N. Y.* 1:8)

Plant consisting of subcylindric or compressed stems, usually flattened on the rock surfaces and having numerous spreading branches, which in some species are leaf-like.

**Bythotrephis gracilis** Hall (Fig. 25) (1852. *Pal. N. Y* 2:18, pl. 5)

*Distinguishing characters.* Slender branches diverging at varying angles from a central stipe which not infrequently bifurcates. Terminations of branches round to pointed.

[1] In this chapter only the Siluric fossils of the Niagara region will be considered, those of the Devonic limestones, which border this region on the south being so numerous that they must be reserved for a future publication. No attempt is made to add to the number of known species of Siluric fossils of the Niagara region. Of described species those only which have been found in this region or recorded in the literature as coming from it have been included, with the addition of such species from neighboring localities as occur there abundantly, and may reasonably be expected to occur in the Niagara sections. An exhaustive study of the Niagara fauna of western New York has still to be made. In chapter 5 a complete account of all the post-Pliocene shells so far found in the Niagara gravels is given, this being the first time that these shells are described and illustrated.

These organisms occur as mere impressions on the rock surfaces, varying in slenderness of branches from less than 1 mm to 5 mm (varieties intermedia and crassa).

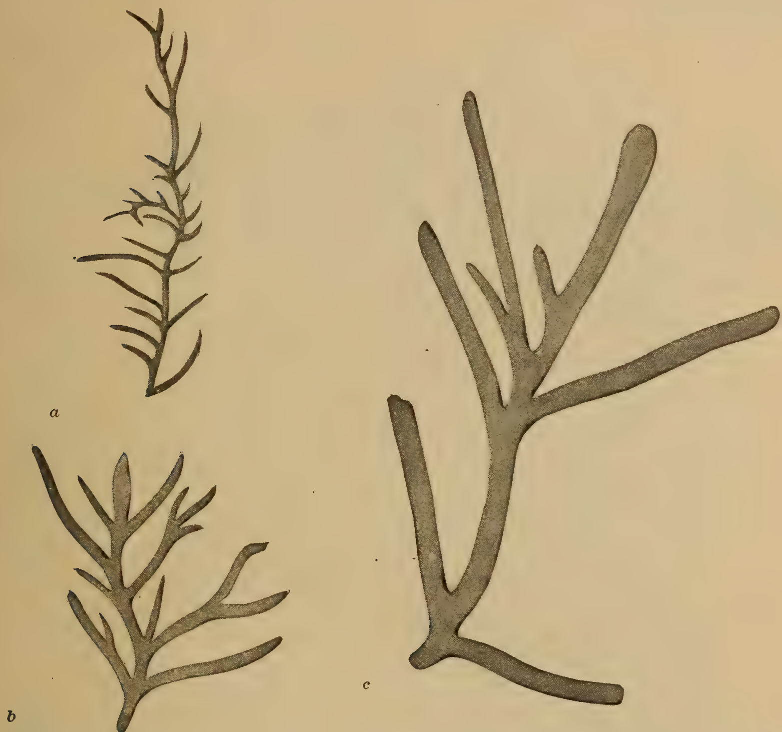


Fig. 25 Bythotrephis gracilis; showing varieties. *a* B. gracilis; *b* B. gracilis var. intermedia; *c* B. gracilis var. crassa

Found in the shaly partings separating the thin beds of the lower Clinton limestone at Niagara.

**Bythotrephis lesquereuxi** Grote & Pitt (Fig. 26) (1876. *Buffalo soc. nat. sci. Bul.* 3:88, 4:20, fig. 6)

*Distinguishing characters.* Flattened, erect stem; simple, sparingly dichotomous branches, 3-4 mm thick, gradually widening to nearly 1 cm at the very obtuse or round truncate point;

Fig. 26 Bythotrephis lesquereuxi

smooth surface; branches mostly simple from the base 13-14 cm long.

Found in the cement beds of the Waterlime, Buffalo (N. Y.) (Grote & Pitt)

Genus ARTHROPHYCUS Hall

[Ety.: ἄρθρον, a joint; φῦκος, a seaweed]

(1852. *Pal. N. Y.* 2:4)

Stems simple or dividing at the beginning and remaining simple thereafter; rounded or subangular, flexuous, transversely marked by ridges or articulations.

**Arthrophycus harlani** (Conrad) (Plate 16) (1852. *Pal. N. Y.* 2:5, pl. 1 and 2)

*Distinguishing characters.* Strong, rounded articulated stems, dividing near the base into numerous elongated branches; simple, flexible, articulated branches which diminish in size very gradually.

Found on the under side of certain sandstone beds in the upper part of the Medina in the Niagara section.

Genus NEMATOPHYCUS Carruthers

[Ety.: νῆμα, thread; φῦκος, seaweed]

(1872. *Month. micro. jour.*)

Considered a gigantic alga, with cylindric branching stems, and a peculiar structure which led Dawson to refer it to the Coniferae under the name Prototaxites. What resemble concentric rings of growth and medullary rays appear; cells irregular, cylindric, thick walled. The specimens are generally silicified.

**Nematophycus crassus** (Penhallow) (1896. Nematophyton crassum Penhallow. *Can. record of science.* July 1896, 7:151-56, pl. 2)

*Distinguishing characters.* Section showing numerous irregular round or oval medullary spots; large cells in groups, thick walled.

The specimen is the basal portion of a stock showing root processes; length 56 cm, diameter at upper end 7.5 cm, widening toward base to 16.5 cm.

Found in the Manlius limestone of North Buffalo. (F. K. Mixer)

Plate 16

Arthrophycus harlani Conrad; upper Medina sandstone. Slightly reduced (original)

## ANIMALS

### Class HYDROZOA Owen

This class includes the simplest polyps, of which the fresh-water Hydra is an example. The body consists of a hollow tube, the walls of which are composed of two cellular layers, *ectoderm* and *endoderm*, with a non-cellular layer, the *mesogloea*, between them. These layers meet at the mouth, which is the only opening into the gastric space inclosed by the body wall. Tentacles, furnished with nettle cells, surround the mouth.

A few hydroids are simple forms, but the majority are united into colonies, which frequently assume a branching or tree-like character, a polyp occupying the end of each branch. Reproduction is usually carried on by specially modified polyps, the *gonopolyps*, which produce jellyfish or medusae. These may remain attached to the colony or become free-swimming.

Some hydroids are entirely unprotected, no hard structures being developed, and these consequently leave no remains. The majority of species, however, secrete a horny or chitinous covering, the *periderm*, which invests the whole stock, and in one group is expanded at the ends of the branches into cups or *hydrothecae*, into which the polyps can withdraw. This chitinous periderm may be preserved in the form of a carbonaceous film (e. g. Dictyonema and Graptolites).

Some hydroid colonies, i. e. the hydrocorallines, secrete at the base a dense calcareous covering, which has much the aspect of coral, and is frequently mistaken for that (e. g. Millepora, Stromatopora). Most hydroid colonies are permanently attached to rocks, seaweeds, or other objects of support.

### Genus DICTYONEMA Hall

[Ety.: δίκτυον, net; νῆμα, thread]

(1852. *Pal. N. Y.* 2:174)

Colony forming a network of anastomosing branches, the whole commonly flattened on the rock surface, but originally forming a funnel or fan-shaped expansion. The branches proceed from a common acute base, divide frequently, and are at intervals united again by transverse dissepiments. The outer surfaces of the branches are striated; the inner bear hydrothecae, though these are seldom seen in the flattened specimens.

**Dictyonema retiforme** Hall. (Fig. 27) (1852. *Pal. N. Y.* 2:174, pl. 40F)

*Distinguishing characters.* Form circular or cup-shaped in growing state; thin, flat, frequently bifurcating branches, united laterally by obliquely transverse filaments, leaving oblong quadrangular interstices; indented or obliquely and intermittently striated surfaces.

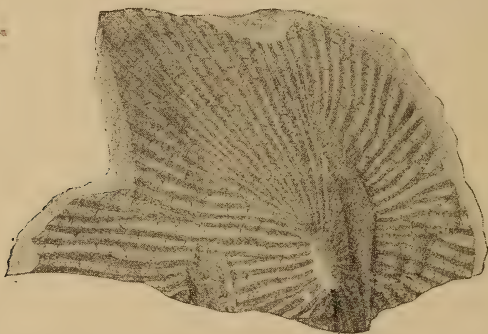

Fig. 27 Dictyonema retiforme

Found rarely in the lower part of the Rochester shales in the Niagara section; usually fragmentary. Abundant at Lockport and elsewhere. (Hall)

Genus STROMATOPORA Goldfuss

[Ety.: στρῶμα, a covering; πόρος, a pore]

(1826. *Petrefacta Germaniae*, p. 22)

Skeleton forming hemispheric, globular or expanded masses composed of numerous concentric, undulating calcareous laminae, separated by interspaces, and connected by radial pillars which unite with the thick concentric laminae and form a finely reticulate tissue, visible in cross-section. Traversing the entire mass are sparsely scattered tubes which are divided by numerous tabulae or horizontal floors, and were occupied by the larger polyps of the colony. Base of entire skeleton covered by a wrinkled " epitheca ".

**Stromatopora concentrica** Goldfuss Hall (Fig. 28) (1852, *Pal. N. Y.* 2:136, pl. 37)

*Distinguishing characters.* Hemispheric or spheroidal form sometimes irregular; thin concentric laminae, readily visible in weathered specimens, and scarcely of the thickness of writing paper; surface of laminae marked by fine pores.

This coralline is generally very massive and may attain a diameter of 2 feet. Probably includes a number of distinct species.

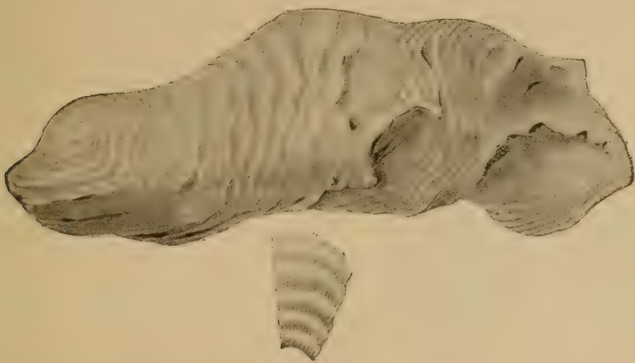

Fig. 28 Stromatopora concentrica Hall with an enlargement of a cross-section

Found at Niagara in the Lockport limestone, particularly the geodiferous beds, and generally common throughout the middle limestones. Also at Lockport and elsewhere.

## Class ANTHOZOA Ehrenberg

The Anthozoa, or coral polyps, are marine animals ranging from low water to 300 and sometimes even 1500 fathoms (Zittel). The reef-building types however do not flourish in depths greater than 50 fathoms, and are generally restricted to 20 fathoms or less. Both simple and colonial forms occur, the latter predominating at the present time, while the former were abundant in the Paleozoic. The two important types of Paleozoic corals are the "rugose corals" or Tetracoralla, and the tabulate corals, the former generally simple, the latter colonial types.[1]

The simple rugose corallum is well represented by Enterolasma. It consists of numerous radiating *septa*, disposed in several cycles, and united round their outer margins by a wall or *theca* (*pseudotheca*). This is formed by the lateral expansion or thickening of the septa in that region. The exothecal prolongations of the septa are visible on the exterior of the corrallum as costae, which are frequently represented by grooves instead of ridges. These, in the genus referred to, as well as in others, commonly show the peculiar tetrameral arrangement characteristic of the septa of this group. On or near the convex longitudinal surface of the corallum a median, or " cardinal ", septum appears, from which the

[1]As no true Hexacoralla occur in the formations treated of in these pages, an account of their structure is omitted.

secondary septa pass off in a pinnate manner (fig. 29). 90° toward either side occur the "alar" septa. These are parallel[1] to the secondary septa which branch off from the cardinal septum. They have a single series of secondary septa branching off from them on the side away from the *cardinal quadrants*. The two remaining, or *counter quadrants*, are filled with parallel septa, which branch off, in a pinnate manner, from the alar septa, and are completed in front by the *counter septum* to which they are all parallel.

One of the four "primary septa"—commonly the cardinal septum—may be aborted, leaving a groove or *fossula*. Between the septa various endothecal tissues may be developed, such as cross plates, or *dissepiments* connecting adjoining septa; *tabulae*, or floors more or less completely dividing the whole inner space, irrespective of the septa; and *cysts*, which form a vesicular tissue more or less regularly disposed (Cystiphyllum). The cup or calyx may be limited below by a continuous floor, by dissepiments or otherwise, or it may be limited only by the margins of the septa, the spaces between the septa being open to the bottom of the corallum. The costae are commonly covered by a concentrically wrinkled *epitheca*, which forms the outermost wall of the corallum.

In colonial forms the adjacent corallites commonly become prismatic from crowding. The separate thecae may be retained, or they may become obsolete, the corallites becoming confluent. The epithecal covering in these forms is commonly confined to the free margins of the outer corallites, and surrounds the whole colony as a *peritheca*.

The tabulate corals are invariably compound, either loosely or compactly, and consist of tubular or prismatic corallites commonly with thick walls, which in certain groups are perforated by *mural pores*. Septa are absent or but slightly developed, sometimes being represented merely by vertical ridges or rows of spines. The number is usually six or 12. The corallites are crossed by numerous *tabulae* which cut off the empty portion of the tube below the polypite. Other endothecal structures are absent.

The reproduction of the Anthozoa is both sexual and asexual, the latter by lateral or calycinal budding, or by fission.

## Genus ENTEROLASMA Simpson

[Ety.: ἔντερον, intestine; ἔλασμα, lamella]

(1900. *N. Y. state mus. Bul.* 39, p. 203)

Corallum simple, turbinate and usually straight. Septa numerous, those of the earlier cycles reaching nearly to the center, where they have projections which reach to the center, becoming much involved and forming a pseudocolumella of very peculiar appear-

[1] Parallel as seen in the costae.

ance, somewhat resembling the convolutions of the intestine; those of the last cycles short; all with papillate elevations or carinae on the sides, giving in section a crenulate or echinate appearance. Dissepiments present. Epitheca well developed.

**Enterolasma caliculus** (Hall) (Fig. 29) Streptelasma caliculus Hall (1852. *Pal. N. Y.* 2:111, pl. 32)

*Distinguishing characters.* Turbinate, oblique or curved, more or less rapidly expanding form; moderately deep cup; septa 20 to 50, separated by a space of twice their width; well marked costal grooves which lie opposite both long and short septa; relatively thin and smooth epitheca.

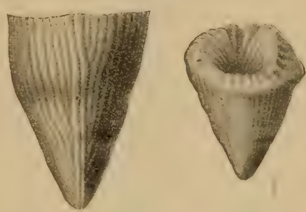

Fig. 29 Enterolasma caliculus

Found rarely in the upper Clinton beds, and abundantly in the lenses of limestone in the Clinton, the lower part of the Rochester shales and the Bryozoan beds of these shales. Also in the same shales at Lockport and farther east.

Genus ZAPHRENTIS Rafinesque

[Ety.: ζα, many; φρήν, diaphragm]

(1820. *Ann. des sci. phys.* Brux. 5:234)

Corallum simple, conic or turbinate, or conico-cylindric, with a deep calyx, and well developed septa, the primary ones reaching to the center. Dissepiments and tabulae occur, the latter usually well developed. A deep fossula marks the abortion of one of the four primary septa. Costae and a thin epitheca occur.

**Zaphrentis turbinata** (Hall) (Fig. 30). Polydilasma turbinatum Hall (1852. *Pal. N. Y.* 2:112, pl. 32)

*Distinguishing characters.* Form variable, usually short and turbinate; calyx gradually deepening from margin halfway to the center and then abruptly descending, almost vertically to a moderate depth; alternate septa terminating at point of sudden deepening of calyx, others reaching to center; dissepiments slightly developed.

Found in the Lockport limestone at Niagara(?) and Lockport, where it occurs a few feet above the shale.

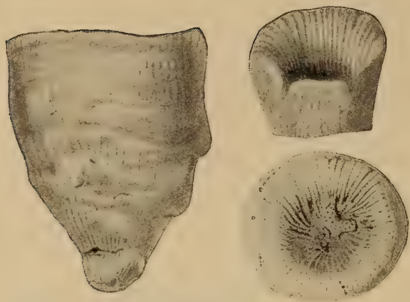

Fig. 30 Zaphrentis turbinata

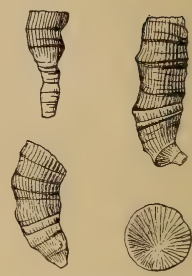

Fig. 31 Cyathophyllum hydraulicum

## Genus CYATHOPHYLLUM Goldfuss

[Ety.: *κύαθος*, a cup; *φύλλον*, a leaf (septum) ]

(1826. *Petrefacta Germaniae*, p. 54)

Corallum normally simple, the individuals conic, or conico-cylindric. Septa well developed, radially arranged, the larger extending to the center, where they are twisted into a pseudocolumella. Costae usually obsolete. Tabulae present but only in the center of the visceral chamber, the outer area being filled with vesicular dissepiments. Exterior covered with an epitheca.

**Cyathophyllum hydraulicum** Simpson. (Fig. 31) Grabau. Geol. soc. Am. Bul. 11:364, pl. 21, fig. la-d.

*Distinguishing characters.* Simple, conico-cylindric, slender, sometimes curved; growth irregular with abrupt changes in direction; strongly costate adult portion; non-costate young; well developed epitheca, which often shows coarse wrinkles; calyx somewhat less deep than its diameter; numerous strong thin and rather widely separated septa, meeting in center where they are slightly twisted, and not infrequently uniting before they reach the center; well developed dissepimental structures.

Found abundantly in the upper Manlius limestone of the Niagara region, but only as external molds in the limestone. Gutta percha casts however show the characters well.

Genus CHONOPHYLLUM Edwards & Haime

[Ety.: χόνος, a funnel; φύλλόν, a leaf (septum) ]

(1850. *British fossil corals*, p. 69)

Corallum simple, chiefly consisting of a series of funnel-shaped tabulae, set one into the other. On the surfaces of these, equally developed septal radii extend from center to circumference; no walls or columella.

**Chonophyllum niagarense** Hall (Fig. 32) (1852. *Pal. N. Y.* 2:114, pl. 32)

*Distinguishing characters.* Irregularly cylindric, elongated or subturbinate form, more or less expanding above; deep and regularly concave calyx; thin denticulate septal ridges, which are separated by a space equal to their width; rough external surface of weathered specimens.

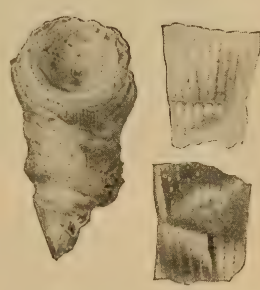

Fig. 32 Chonophyllum niagarense with enlargement of interior of calyx

Hitherto found only in the lower part of the Lockport limestone at Lockport, but probably also occuring at Niagara.

Genus DIPLOPHYLLUM Hall

[Ety.: διπλόος, double; φύλλον, septum]

(1852. *Pal. N. Y.* 2:115)

Corallum simple and branching, or forming compound masses of loosely aggregated corallites which are cylindric, consisting of two distinct parts separated by an accessory wall, the inner transversely septate, the outer with fine transverse dissepiments uniting the septa which are continuous to the center. Calyxes deeply concave in the center, and separated from the outer portion by a distinct rim.

**Diplophyllum caespitosum** Hall (Fig. 33) (1852. *Pal. N. Y.* 2:116, pl. 33)

*Distinguishing characters.* Subturbinate young, and cylindric adult corallites, which coalesce at intervals and increase by lateral budding; cespitose or aggregated into large masses which often grow from a single base; strongly costate exterior; numerous thin septa, all of which reach the center.

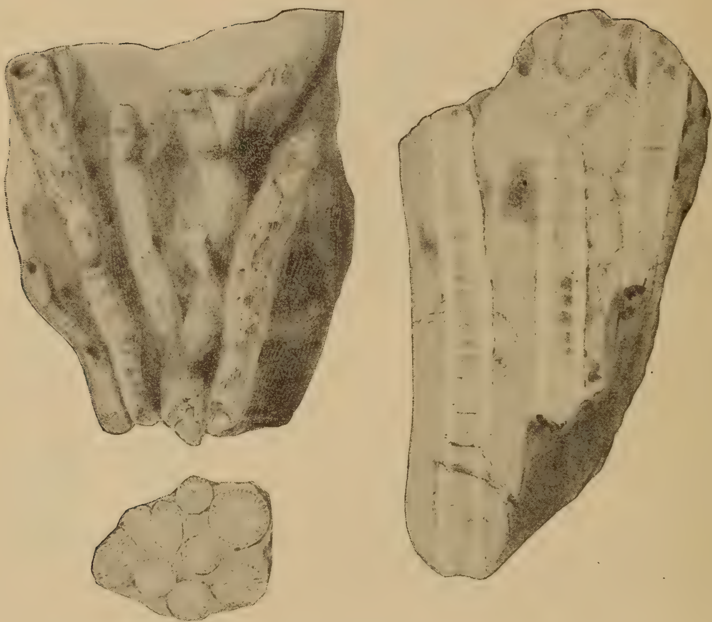

Fig. 33 Diplophyllum caespitosum with longitudinal and transverse sections

Found in the lower part of the Lockport limestone series at Lockport, and may also occur at Niagara.

Genus FAVOSITES Lamarck

[Ety.: *favus*, honeycomb]

(1816. *Hist. des anim. sans vert.* 2:204)

Corallum massive, more rarely branching, commonly forming heads which may be a foot or more in diameter. Corallites prismatic, thin, in contact but not amalgamated by their walls, which are perforated by equidistant mural pores in one or more rows. Septa rudimentary or obsolete. Numerous more or less regular tabulae divide the intrathecal space. Peritheca present on the under side of the colony, and usually strongly wrinkled.

**Favosites venustus** (Hall)[1] (Fig. 34). Astrocerium venustum Hall (1852. *Pal. N. Y.* 2:120, pl. 34)

*Distinguishing characters.* Hemispheric or spheroidal form, beginning growth on other bodies; small corallites increasing in number by interstitial addition; 12 ascending septal spines between tabulae; corallites from .9 to 1 mm in diameter; heads often up to 2 or 3 feet in diameter.

[1]These species are regarded by Whiteaves and Lambe as synonyms of Favosites hisingeri E. and H.

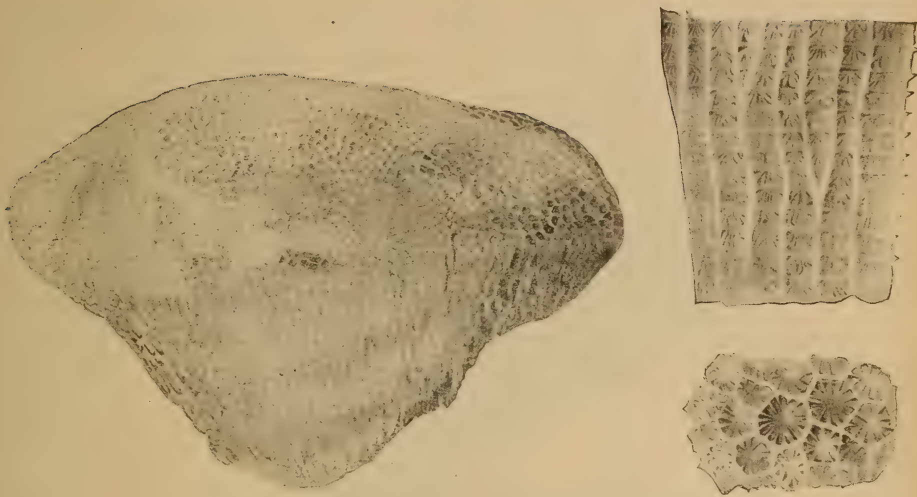

Fig 34 Favosites venustus with longitudinal and transverse sections

Found in the Lockport limestone at Lockport and Niagara, often replaced by anhydrite or other materials.

**Favosites parasiticus** (Hall)[1] (Fig. 35). Astrocerium parasiticum Hall (1852. *Pal. N. Y.* 2:122, pl. 34) Not F. parasiticus Phillips.

*Distinguishing characters.* Hemispheric or spheroidal coralla, independent or attached to, or enveloping other bodies; unequal size of calyxes, which are stellate from septal spines, of which there are from 12 to 24; subcircular outline of some of the larger calyxes, the majority being angular.

Fig. 35 Favosites parasiticus

Found in the Bryozoan bed of the Rochester shales in the Niagara sections. Also in the lower part of the limestone at Lockport (Hall).

**Favosites pyriformis** (Hall)[1] (Fig. 36). Astrocerium pyriforme Hall (1852. *Pal. N. Y.* 2:123, pl. 34A)

*Distinguishing characters.* Irregularly subturbinate, pyriform or spheroidal form of corallum; corallites radiating from a more or less extended base, spreading out above and rapidly increasing in number by interstitial addition; calyxes varying from triangular to

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[1]These species are regarded by Whiteaves and Lambe as synonyms of Favosites hisingeri E. and H.

hexagonal, not rounded and varying in size according to age of individual; septal spines in one or more rows.

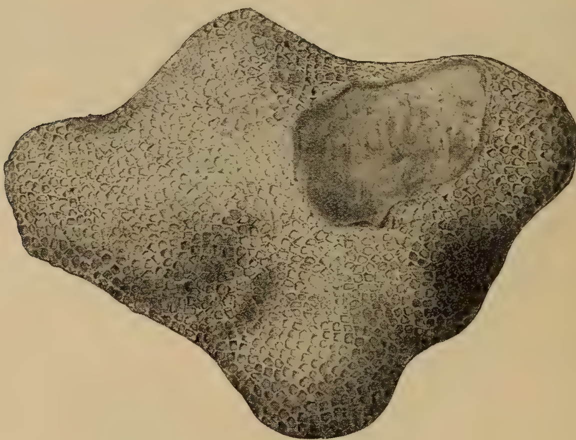


Fig. 36 Favosites pyriformis

Found in the Rochester shale and Lockport limestone at Lockport (Hall). Probably occurs also at Niagara.

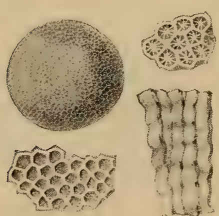


Fig. 37 Favosites constrictus; a group of corallites enlarged, and enlargements of the calyxes

**Favosites constrictus** (Hall) (Fig. 37). A s t r o c e r i u m c o n s t r i c t u m Hall (1852. *Pal. N. Y.* 2:123, pl. 34A)

*Distinguishing characters.* Small size; hemispheric form; minute corallites which appear constricted at intervals; calyxes appear stellate.

Found in the Rochester shale at Lockport and other places (Hall). Probably also at Niagara.

**Favosites niagarensis** Hall (Fig. 38) (1852. *Pal. N. Y.* 2:125, pl. 34A)

*Distinguishing characters.* Spheroidal to irregular form, rapidly increasing in size by interstitial addition of corallites; thin walled corallites with mural pores in double rows; tabulae often oblique or bent downward; calyxes varying in size with varying age of individual; septal spines obsolete.

Found in the Lockport limestone at Niagara and Lockport.

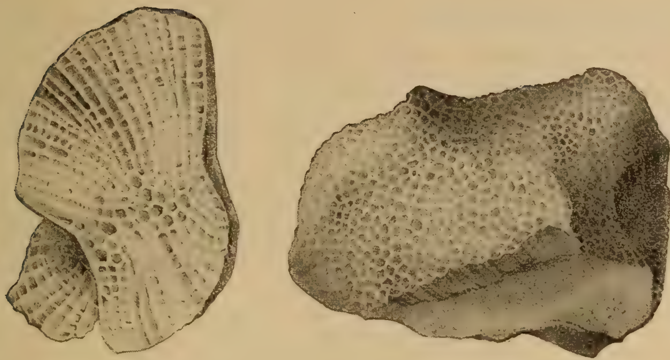


Fig. 38 Favosites niagarensis

Genus HALYSITES Fischer

[Ety.: ἅλυσις, a chain]

(1813. *Zoognosia.* 3d ed. t. 1, p. 387)

Corallum forming a clustered and reticulated mass, composed of long tubular, cylindric or compressed corallites, which are placed side by side in intersecting and anastomosing laminae or lines, any given corallite being united along its whole length with its neighbors to the right and left, and each lamina of the corallum consisting of no more than a single linear series of tubes. Walls of the corallites strong and without pores, the free portions covered by a continuous thick epitheca showing lines of growth. Small corallites often alternate with the larger ones. Septa obsolete or represented by vertical rows of spines in cycles of 12. Tabulae well developed, complete and simple, more numerous in the smaller corallites.

**Halysites catenulatus** (Linn.) (Fig. 39). Catenipora escharoides (Lamarck) Hall (1852. *Pal. N. Y.* 2:127, pl. 35)

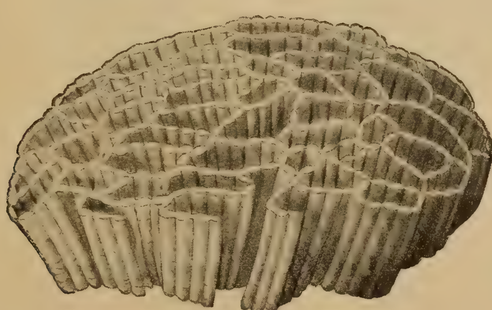


Fig. 39 Halysites catenulatus

*Distinguishing characters.* Corallites in juxtaposition or separated by cellular interspaces; large meshes of the network irregular, greatly varying in size; corallites oval in cross-section, united by their narrower sides; epitheca with fine lines of growth and occasionally strong wrinkles.

Found in the Lockport limestone at Lockport (Hall), and Niagara. When silicified, the coral may be well preserved, but otherwise it is usually almost destroyed or replaced by various minerals.

Genus HELIOLITES Guettard

[Ety.: ἥλιος, the sun; λίθος, a stone]

(1770. *Mem.* 3:454)

Corallum spheroidal, pyriform, hemispheric, or rarely ramose. Corallites (macrocorallites) cylindric, comparatively few in number

Fig. 40 Heliolites elegans with enlargement of calyxes and longitudinal section

and furnished with 12 lamellar infoldings of the wall, or pseudosepta. Smaller corallites (microcorallites) completely investing the larger ones, more or less regularly polygonal in form, with distinct walls, completely amalgamated with one another and with the walls of the larger corallites. Mural pores absent. Both kinds of corallites with tabulae, most numerous in the smaller corallites. Base of corallum covered by a peritheca showing lines of growth.

**Heliolites elegans** Hall (Fig. 40) (1852. *Pal. N. Y.* 2:130, pl. 36)

*Distinguishing characters.* Hemispheric form of corallum, which increases in size by lateral rather than interstitial addition; from 16 to 18 larger calyxes to the inch; pseudosepta reaching halfway to the center; microcorallites generally appearing solid; macrocorallites often standing out in relief in weathered specimens and having a stellate appearance.

Found in the lower part of the Lockport limestone at Lockport (Hall). May occur also at Niagara.

**Heliolites spiniporus** Hall (Fig. 41) (1852. *Pal. N. Y.* 2:131, pl. 34)

*Distinguishing characters.* Turbinate, pyriform, hemispheric or spheroidal form of corallum; divergent corallites, increasing in

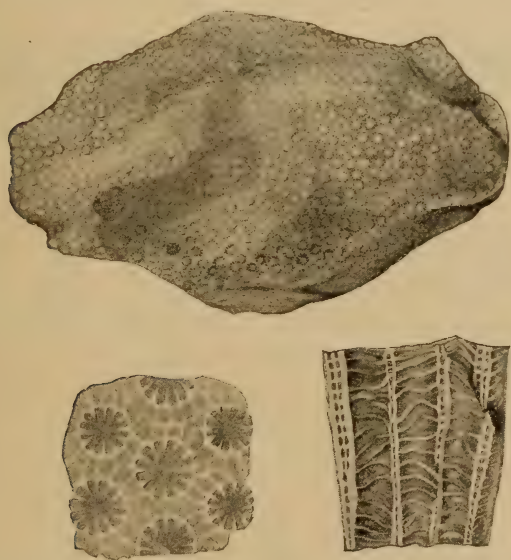


**Fig. 41 Heliolites spiniporus with longitudinal and transverse sections enlarged**

number by interstitial addition; circular macrocorallites with 12 pseudosepta, which extend only part way to the center; irregular or interrupted tabulae which often appear spiniform in section; microcorallites in one or more series, angular and tabulate.

Found in the lower part of the Lockport limestone at Lockport (Hall). Probably also at Niagara.

**Heliolites pyriformis** Guettard (Fig. 42) (Hall. 1852. *Pal. N. Y.* 2:133, pl. 36A)

*Distinguishing characters.* Macrocorallites larger than preceding, and generally more widely separated; mostly several series of micro-

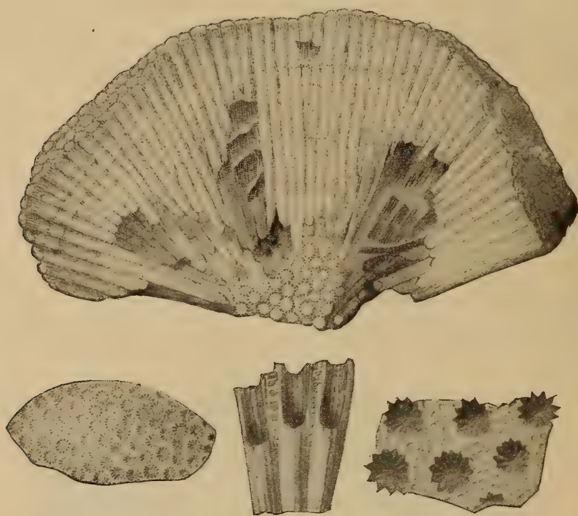


Fig. 42 Heliolites pyriformis

corallites, though they may sometimes be absent when macrocorallites are in contact; short pseudosepta.

Found commonly in the lower Lockport limestone at Lockport (Hall). Probably also at Niagara.

### Genus CLADOPORA Hall

[Ety.: κλάδος, twig; πόρος, pore]

(1852. *Pal. N. Y.* 2:137)

Corallum branching or reticulate; branches cylindric or slightly compressed with terete terminations. Corallites small, radiating equally on all sides from the axis, and opening on the surface in rounded or subangular expanded calyxes, which are generally contiguous, and apparently destitute of septa.

**Cladopora seriata** Hall (Fig. 43) (1852. *Pal. N. Y.* 2:137, pl. 38)

*Distinguishing characters.* Nearly parallel, rather closely crowded branches, forming a glomerate mass, the branches sometimes

bifurcating; closely arranged corallites, gradually enlarging toward the surface of the branches. Calyxes in alternating series each margined on the lower side by a projecting circular lip.

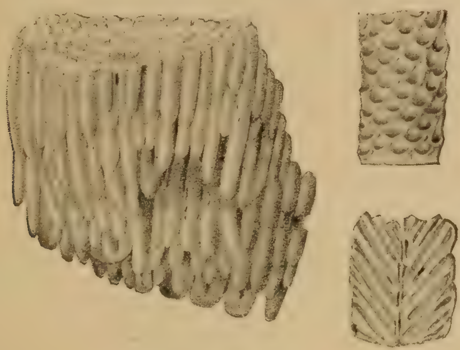


Fig. 43 Cladopora seriata with enlargement of a single branch showing the calyxes, and a section of same showing position of corallites

Found in the lower part of the Lockport limestone at Lockport (Hall), and in the Bryozoan bed of the Rochester shale at Niagara.

**Cladopora multipora** Hall (Fig. 44) (1852. *Pal. N. Y.* 2:140, pl. 39)

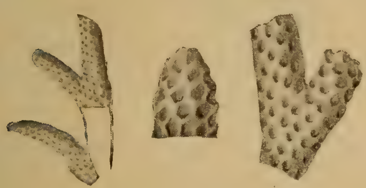


Fig. 44 Cladopora multipora, with enlargements

*Distinguishing characters.* Ramose or irregularly reticulate form, with the branches often extending beyond the last point of junction and ending in terete extremities; numerous closely arranged corallites, which are slightly oblique to the axis; calyxes subangular or circular, from 48 to 60 in the space of an inch.

Found in the lower part of the Lockport limestone at Lockport (Hall). Probably occurs also at Niagara.

## Genus STRIATOPORA Hall

[Ety.: *striatus*, striated; *porus*, pore]

(1852. *Pal. N. Y.* 2:156)

Corallum dendroid, forming simple dividing, cylindric stems. Corallites essentially polygonal, diverging from an imaginary central axis, their walls greatly thickened by a secondary deposit of cal-

careous material or sclerenchyma, which increases in amount toward the calyxes. Calyxes in the form of circular apertures surrounded by a cup-shaped, thickened margin, the floor of which is striated by rudimentary septal ridges. Septal spines in vertical rows occasionally present. Tabulae few, widely separated, but extending completely across. Mural pores comparatively numerous, circular, and irregularly distributed.

**Striatopora flexuosa** Hall (Fig. 45) (1852. *Pal. N. Y.* 2:156, pl. 40B)

*Distinguishing characters.* Bifurcating or irregularly ramose stems with teretely terminating branches; calyxes circular, surrounded by large depressed cells, polygonal in outline and bounded by angular ridges; calycinal orifice in lower part of polygonal cell, vertically striate, the stria continuing upward in the surrounding cell.

**Fig. 45 Striatopora flexuosa with an enlargement of several calyxes**

Found not uncommonly in the Bryozoan bed of the Rochester shale at Niagara, generally well weathered out. Also in the same shale at Lockport (Hall).

## Class CYSTOIDEA von Buch

The cystoids are entirely extinct marine invertebrates which flourished only during Paleozoic time. Most of them lived during the Ordovicic or Siluric eras, but Cambric and Carbonic forms are also known. They were mostly stemmed organisms with a *calyx* and imperfect *arms* like the crinoids, but a few of them were stemless. The *calyx*, which varies in form, is composed of polygonal plates which are united by close *sutures*. The plates vary in number in different species, from 13 to several hundred, and only exceptionally exhibit a regular arrangement. A radial arrangement of plates, like that of the Crinoidea occurs rarely, and the

side plates pass insensibly into the plates of the ventral (upper) side. In the center of the dorsal side, however, a regular series of *basal plates* exists, which rest on the stem or column.

The mouth is indicated by a central or subcentral aperture on the upper (ventral) surface, and is sometimes covered by small plates. From it radiate from two to five simple or branching ambulacral grooves, which are also frequently roofed over by plates. The *anal opening* is situated eccentrically and frequently closed by a valvular pyramid.

The calyx plates in most cystoids are perforated by pores or fissures. These are often arranged to form lozenge-shaped or rhombic figures, the *pore rhombs,* which are disposed one half on each of two adjoining plates, while the line of suture between the plates forms either the longer or the shorter diagonal of the rhomb. The pores of opposite sides of the rhomb are united by perfectly closed, straight ducts, which pass horizontally across the line of suture, and produce a transversely striated appearance (Caryocrinus, fig. 46). These striate rhombs are generally visible only in weathered specimens. They may be present on all plates or only on a few. In Callocystites and other related genera, the *pore rhombs* are reduced to *pectinated rhombs,* which are few in number, and each separated into two distinct parts, lying on contiguous plates (fig. 47). These structures have probably a respiratory function.

The *arms* are feebly developed in the cystoids and often but few in number. They are simple, consisting of a single (uniserial) or a double (biserial) row of plates, and possess a ventral groove, protected by covering plates.

### Genus CARYOCRINUS Say

[Ety.: κάρυον, a nut; κρίνον, lily]

(1825. *Acad. nat. sci. Phil. Jour.* 4:289)

Calyx composed of a moderate number of plates arranged in a hexamerous manner, and with the base composed of two cycles of plates (dicyclic). Lowest (*infrabasals*) four, unequal; followed by a second row of six basals, which alternate in position with those of the preceding and succeeding cycles. Third cycle of eight plates of which six are regarded as *radials,* the others as *interradials* (Carpenter). Ventral surface formed of six or more small pieces. All plates of the calyx furnished with pore-rhombs; the summit plates without perforations. Mouth and ambulacral grooves below the ventral plates or *tegmen.* Anal opening protected by a valvular pyramid, and situated on the outer margin of the ventral surface. Arms, 6 to 13 in number, situated on the ventral margin, and relatively feeble. Stem long, composed of cylindric segments.

**Caryocrinus ornatus** Say (Fig. 46) (Hall. 1852. *Pal. N. Y.* 2:216, pl. 49 and 49A)

*Distinguishing characters.* Stem of larger and smaller joints alternating near the calyx; edges of joints thin and sharp, sometimes slightly crenulated or denticulated; articulating surface radiately striate halfway to the center; canal round; calyx ovoid to subglobose, the greatest diameter usually below the middle; summit

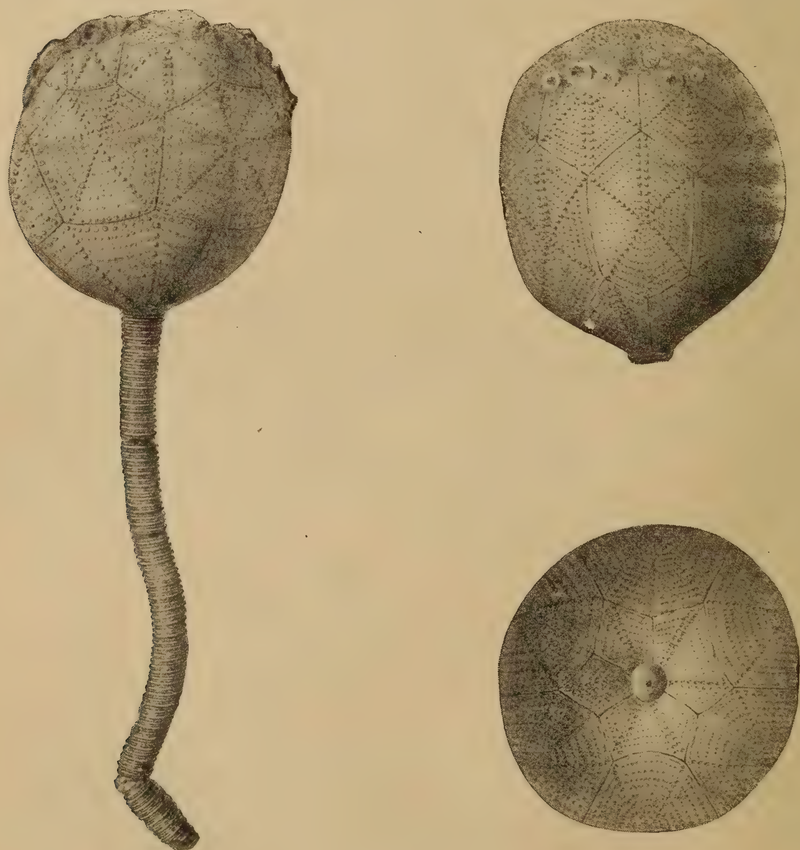


Fig. 46 Caryocrinus ornatus

slightly convex with arms sometimes several inches long; upper margins of radial and interradial plates indented for the arm plates. Mural pores represented on the exterior of the plates by single or double rows of tubercles radiating from the centers of the plates to their angles; between these are numerous rows of smaller tubercles parallel to the sides of the plates.

Found in the Rochester shale at Niagara, Lockport and other places. Often very abundant. At Niagara it has been found as low as 4 feet above the Clinton limestone, and from that upward as far as the Bryozoa beds, in which it occurs in moderate abundance. It has not been found above these beds. It occurs chiefly in the calcareous layers of the shale, from which it weathers out, the nut-like calyxes rolling to the bottom of the section where they can be picked up by the side of the railroad track.[1]

Genus CALLOCYSTITES Hall

[Ety.: κάλλος, beauty; κύστις, bladder]

(1852. *Pal. N. Y.* 2:238)

Calyx composed of large plates arranged in three or four cycles and having four pectinated rhombs, the component halves of which stand on contiguous plates and are separated by an interval. Mouth slit-like, and forming the center of radiation for two to five pinnulated arms, which sometimes bifurcate, and are protected by covering pieces, and either repose on the calyx or are sunk below the surface in grooves. Stem well developed. tapering down to a point.

**Callocystites jewetti** Hall (Fig. 47) (1852. *Pal. N. Y.* 2:239, pl. 50)

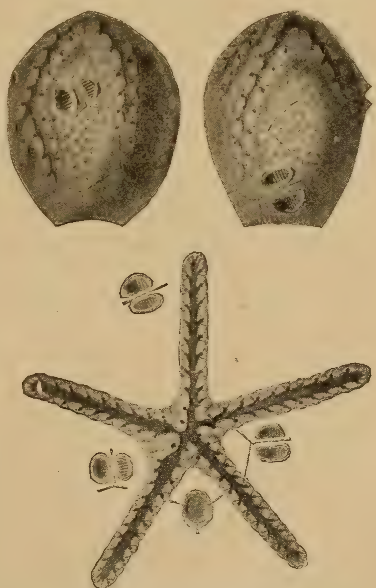


Fig. 47 Callocystites jewetti with the armgrooves spread out

*Distinguishing characters.* Oblong ovoid, nearly symmetric form; base of four plates, one bearing part of pectinated rhomb; eight plates in second cycle; anal aperture between second and third cycle, excavated in two plates of the former and one of the latter; surface of plates ornamented by polygonal depressions, having a more or less defined border and granulose surface.

[1] Specimens of this "crinoid" may be purchased from John Garlow, the watchman on the middle section of the New York Central railroad cut in the gorge, at a moderate price.

Found in the Rochester shale at Lockport (Hall). Isolated fragments of plates have been obtained from the weathered lower Rochester shale in the Niagara gorge.

## Class CRINOIDEA Miller

The crinoids, or sea lilies, are marine invertebrates, represented in the modern seas by a number of genera and species which range from shallow water to a maximum depth of about 3000 fathoms. They are gregarious in habit, and usually of very local distribution. A typical crinoid consists of a dorsal cup or *calyx*, placed on a *stalk* or stem, by means of which it is attached, and bears a fringe of *arms*, variously divided and furnished with jointed appendages, or *pinnules*. The calyx is composed of a number of plates, which have a definite arrangement, in horizontally disposed series (fig. 50). The lowest of these are the *basals*, though in many forms an additional series, the *infrabasals*, may underlie and alternate with the basals. Next above the basals, and alternating with them in position, are the *radials*, five in number, so called because they are in line with the rays or arms. Referring the position of the inferior plates to that of the radials, we find that the basals are always situated *interradially*, while the infrabasal are situated *radially*. Above the radials lie the *brachials*. These vary greatly in number and kind, sometimes articulating directly with the radials, in which case all the brachials are free, and sometimes having their lower series fixed and immovable, thus forming a part of the calyx. The brachials lying directly on the radials are the *costals;* of these there may be one or more series, when they are distinguished from below as *primary* (cost.$^1$), *secondary* (cost.$^2$), etc. The uppermost costal of each ray is commonly axillary, i. e. pentagonal in outline, with two upper joint edges inclined from each other. On these rest the *distichals*, of which there are 10 in each series. Secondary distichals (dist.$^2$) may rest on the primary ones (dist.$^1$), and may in turn support the *palmars*, of which there would be 20 in a normal series. Above these, on farther division, are the *post-palmars*, which are often very numerous. Two types of arms can be distinguished, those composed throughout of one series of plates (uniserial), and those made up of a double series (biserial), the plates of the latter usually interlocking to a greater or less extent. The latter are the more specialized, always beginning uniserially.

Between the radials are often found additional plates, the *interradials*, which may vary in number.

Between the distichals of one ray may occur the *interdistichals*, which are situated *radially*. Between the distichals of adjacent rays may occur the *interbrachials*, and these will be situated *interradially*.

An anal interradius is present in unsymmetric forms. The *tegmen* forms the cover, or ventral part of the calyx, and is composed of plates either closely ankylosed, or held together by a leathery membrane. In the Paleozoic Camerata the plates of the ventral disk fit closely and they are considerably thickened, forming a very rigid, more or less convex vault, from which may rise the plated anal proboscis.

The mouth of Paleozoic camerate crinoids lies beneath the tegmen, the only external opening being that of the anus. From the mouth, radiating grooves or canals commonly pass outward to the arms, in which they are continued. These are the ambulacral grooves, along which the food, caught on the arms, is conveyed to the central mouth. These grooves may be open or covered by plates. Within the cavity of the calyx are the viscera.

The stalk, or *stem*, is composed of a varying number of joints, which are circular, elliptic or angular in cross-section (fig. 52). The joint nearest to the calyx is the last formed except in the Flexibilia. Frequently a certain number of the joints bear rootlike extensions or *cirri*. The stem and cirri are pierced by an axial canal, round or pentagonal in cross-section. The stem was in most cases attached by a root. Some crinoids were without a stem, having been attached by the base directly or more rarely being free-swimming organisms.

### Order LARVIFORMIA Wachsmuth & Springer

#### Genus STEPHANOCRINUS Conrad

[Ety. στέφανος, a crown; κρίνον, a lily]

(1842. *Acad. nat. sci. Phil. Jour.* 8:278)

Calyx cup-shaped, composed of three elongate basals, five radials, and five interradials. Radials deeply forked; the prongs formed by the margins of two continuous radials extending upward between the arms, and building, together with the interradials, a row of five pyramids, near the summit of one of which is situated the anal aperture. Radial incisions occupied by the ambulacral grooves, which are roofed over by two rows of covering pieces; those of the same row closely ankylosed. First costals semilunate, and resting within a horseshoe-like concavity near the outer end of the radial incisions. Tegmen constituted of five large triangular *oral plates*. Arms very short,[1] composed of about 10 pieces, all of which are axillary and give off side arms. The latter are biserial, non-pinnu-

[1] Generally wanting in the weathered-out specimens.

late, and are made up of long, strongly cuneiform joints. Stem consisting of circular joints pierced by a circular axial canal.

**Stephanocrinus angulatus** Conrad (Fig. 48) (Hall. 1852. *Pal. N. Y.* 2:212, pl. 48, 83)

*Distinguishing characters.* Thick, equal stem joints, with crenulated, articulating margins, and minute round canal; form of calyx

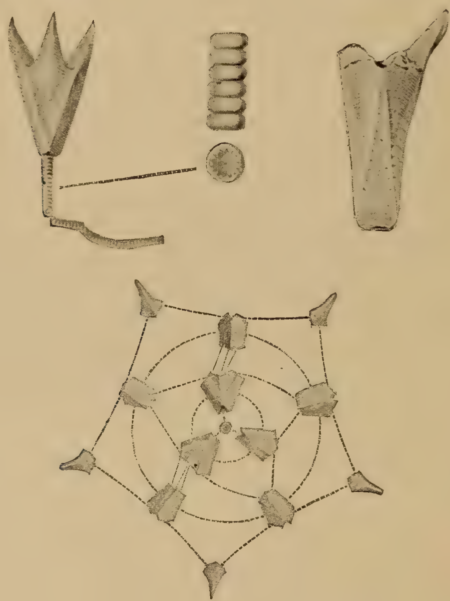


Fig. 48 Stephanocrinus angulatus with an enlargement of the stem and an analysis of the calyx

reverse pyramidal, gradually spreading from a triangular base upward; sutures scarcely visible; three basals, one pentagonal and two heptagonal; radials hexagonal with short excavated upper side; interradials broad below, contracting upward to form the coronal points; strong and angular carinae, six of which alternately converge upward and downward, while two others, somewhat stronger, extend from the bases of the heptagonal basals to the summit of the radials immediately succeeding; elevated tuberculated striae of the plates which extend transversely, vertically or obliquely on different parts of the calyx; surface sometimes merely tuberculated.

Found in certain thin calcareous layers of the lower Rochester shale at Niagara, sometimes quite abundantly. Also in the same shale at Lockport (Hall). The crinoid is generally much lighter in color than the inclosing rock, and is easily distinguished. Associated

with Eucalyptocrinus fragments and other crinoids, as well as other fossils.

**Stephanocrinus gemmiformis** Hall (Fig. 49) (1852. *Pal. N. Y.* 2:215, pl. 48)

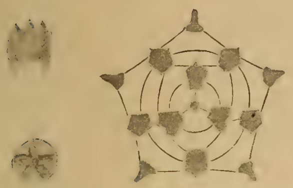


Fig. 49 Stephanocrinus gemmiformis with analysis of calyx

*Distinguishing characters.* Sharply triangular base; rapidly enlarging calyx, which is rotund in the middle and slightly contracted toward the summit. Upper margin of radials scarcely depressed or excavated; granular noncarinate surface of plates; slightly converging coronal processes.

Found in the Rochester shale at Lockport (Hall). Probably also at Niagara.

Order CAMERATA Wachsmuth & Springer

Genus THYSANOCRINUS Hall

[Ety.: θύσᾰνος, fringe; κρίνον, lily]

(1852. *Pal. N. Y.* 2:188)

Calyx deep, with a dicyclic base. Infrabasals and basals five each, the former pentagonal, the latter generally hexagonal. Radials

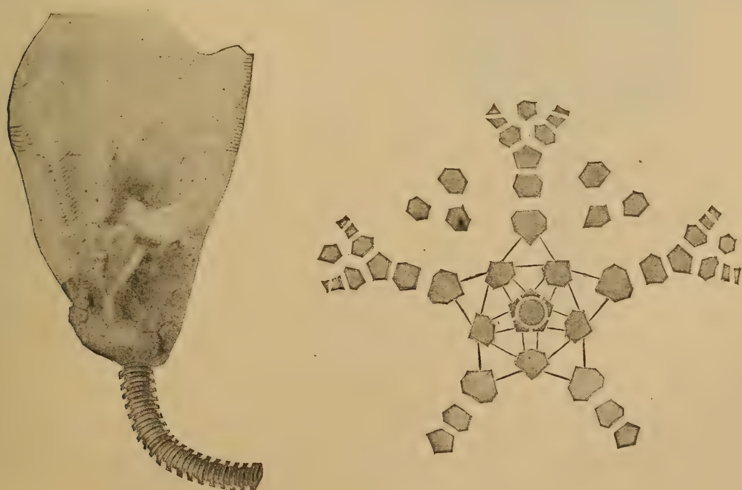


Fig. 50 Thysanocrinus liliiformis with analysis of calyx

five, hexagonal, laterally in contact, except at the azygous side, where they are separated by an anal plate which is succeeded by three in-

terradial plates. Lower brachials forming a part of the calyx; cost.[1] hexagonal, cost.[2] pentagonal, axillary bearing the distichals. Interradials lying chiefly between the costals. Arms 10 to 20, biserial. Stem round.

**Thysanocrinus liliiformis** Hall (Fig. 50) (1852. *Pal. N. Y.* 2:188, pl. 42)

*Distinguishing characters.* Surface of plates ornamented by vertical or radiating, interrupted or crenulated, sharp, elevated striae; small infrabasals, large basals and still larger radials; three distichals in each of the 10 arms, the lowest large and hexagonal, the others cuneiform, followed by the biserial upper arm plates; stem joints round and alternatingly thin and thick, most irregular near the base of the calyx.

Fig. 51 Lyriocrinus dactylus

Found so far only in the Rochester shale at Lockport (Hall), but may also occur at Niagara.

Genus LYRIOCRINUS Hall

[Ety: λύριον, small lyre; κρίνον, lily]

(1852. *Pal. N. Y.* 2:197)

Calyx depressed, with a dicyclic base. Infrabasals five; basals five, pentagonal, truncated at the upper end. Radials separated all around by large interradials, which scarcely differ from the anal interradius. Anal aperture eccentric. Plates of the calyx smooth or finely granulose. Tegmen almost flat, composed of a large number of small plates. Arms 10, strong, simple and biserial. Stem round.

**Lyriocrinus dactylus** Hall (Fig. 51) (1852. *Pal. N. Y.* 2:197, pl. 44)

*Distinguishing characters.* Stem near the calyx of alternating larger and smaller joints, the larger projecting much beyond the

smaller ones; calyx plates finely ornamented by granules, which become elongated near the margins of the plates; two simple distichals in each arm, abruptly followed by the biserial arm plates.

Found in the talus of the weathered Rochester shale above Lewiston, probably from the thin calcareous beds of the lower part of the shale. Also in the same shale at Lockport (Hall).

**Glyptocrinus plumosus** Hall (Fig. 52) (1852. *Pal. N. Y.* 2:180, pl. A41)

Under this name Hall has figured and described fragments of the stem and arms of a crinoid from the Clinton beds of western New York, which he states is extremely rare at Niagara, but often common farther east. The characteristics of these fragments are shown in the illustrations here reproduced.

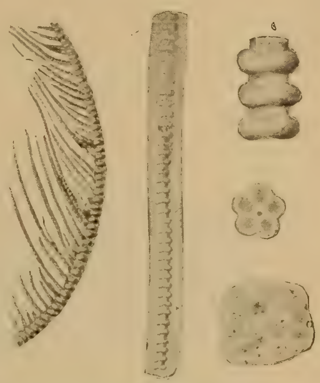


Fig. 52 Glyptocrinus plumosus the arm pinnules and stem with an enlargement of stem joints

Genus EUCALYPTOCRINUS Goldfuss

[Ety.: εὖ, well; καλύπτειν, cover; κρίνον, lily]

(1826. *Petrefacta Germaniae,* p. 212)

Calyx with a deep concavity at the lower end, of which the monocyclic base forms the bottom. Calycinal plates having throughout a pentameral arrangement, except the basals, which are only four in number. Radials in contact all around, costals 2 x 5, distichals 2 x 10, and above these the palmars in cycles of 20, and of small size. There are 1 x 5 large interradials, above which are two narrow and elongate interbrachials placed side by side. Between the distichals is in each ray one interdistichal, which has nearly the form and size of the two interbrachials combined. On the interbrachials and interdistichals and the tegmen rest 10 partitions, which extend upward and form compartments which contain two arms each. Arms biserial, composed of very narrow pieces. A proboscis surmounts the tegmen and projects above the arms. Stem round.

**Eucalyptocrinus decorus** (Phillips) (Fig. 53) (Hall. 1852. *Pal. N. Y.* 2:207, pl. 47)

*Distinguishing characters.* Stem consisting of alternating thicker and thinner joints, the former wider than the latter, with rounded

edges; two or three thin joints between thick ones; articulating surfaces of joints deeply striated radially from margin nearly to the canal; canal pentapetalous; calyx subcylindric or ovoid, gradually enlarging from base upward to commencement of arms, then diminishing; summit contracted; surface of plates generally smooth.

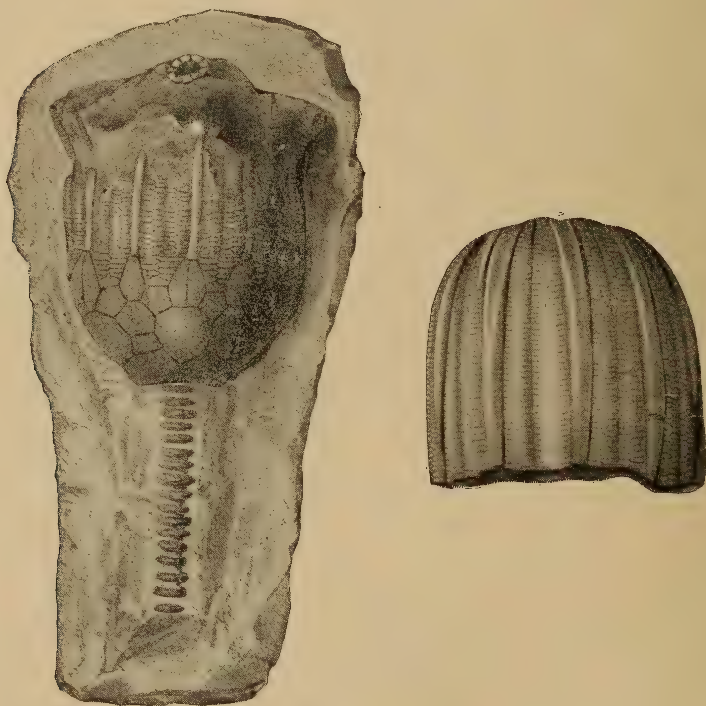


**Fig. 53 Eucalyptocrinus decorus**

Found in the lenses of limestone in the upper Clinton and in the calcareous beds of the lower Rochester shale, as well as the Bryozoan bed at Niagara. Often plentiful but generally in dissociated plates, of which the interbrachial partition plates are most readily recognized. The " roots " are occasionally found attached to corals, etc. Also represented in the middle and upper limestones at Niagara, but generally replaced. Also in the shale at Lockport and other localities (Hall).

### Order FLEXIBILIA Zittel

### Genus ICHTHYOCRINUS Conrad

[Ety.: ἰχθύς, fish; κρίνον, lily]

(1842. *Acad. nat. sci. Phil. Jour.* 8:279)

Calyx with all plates above the radials united by loose suture or by muscular articulation. Base dicyclic; infrabasals three, unequal, very small, rarely extending beyond the top stem joint with which they are fused. Basals five, small. Radials and lower brachials laterally in contact on all sides; no interradials or anals. Brachials united by more or less wavy sutures and their lower edges furnished with tooth-like projections which fit into depressions on the subjacent plates. Tegmen squamous, composed of five orals and numerous, very small, movable plates. Arms non-pinnulate, with a wide, shallow ventral groove. When the arms are folded, the crown appears like a perfectly solid body. Stem round, the upper joints extremely short, and generally wider than the others.

**Ichthyocrinus laevis** Conrad (Fig. 54) (Hall. 1852. *Pal. N. Y.* 2:195, pl. 43)

*Distinguishing characters.* Stem slender, round and smooth, gradually enlarging to the base of the calyx and composed of alternate thick and thin joints; radials five, succeeded by two to four costals in each radius; 10 columns of distichals, from six to nine plates in each, an unequal number in the two columns of each radius; 20 columns of palmars, and 40 of post-palmars, the number of plates varying in the columns of the same individual; plates with lower margins obtusely triangular and upper margins with a corresponding reentrant angle; axillary plates angular above and below.

Fig. 54 Ichthyocrinus laevis with stem enlarged

Found in certain calcareous layers near the middle of the lower Rochester shales at Niagara. Also in the same shales at Lockport (Hall).

Genus LECANOCRINUS Hall

[Ety.: λεκάνη, basin; κρίνον, lily]

(1852. *Pal. N. Y.* 2:199)

This genus differs from Ichthyocrinus only in having a rhomboidal anal plate separating the two posterior radials, and followed by a somewhat larger anal interradial.

**Lecanocrinus macropetalus** Hall (Fig. 55) (1852. *Pal. N. Y.* 2:199, pl. 45)

*Distinguishing characters.* Subglobose calyx; three large infrabasals, the two larger truncated on top; larger basals, two pen-

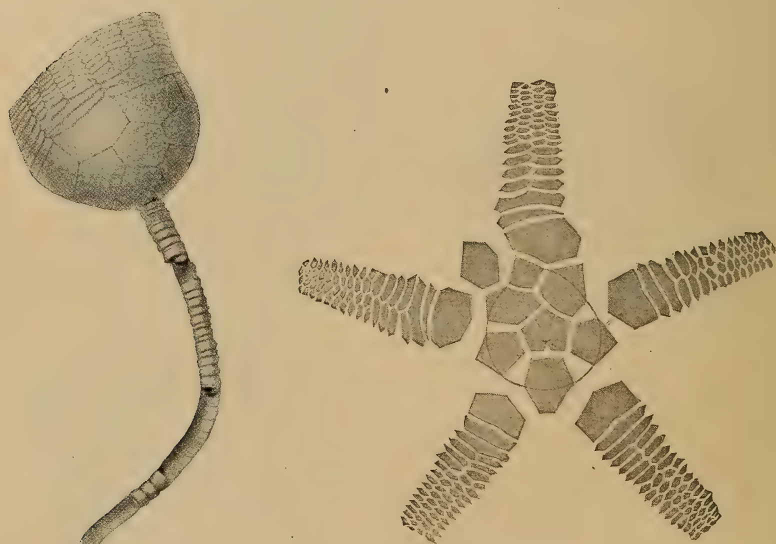


Fig. 55 Lecanocrinus macropetalus with analysis of calyx

tagonal, one hexagonal and two heptagonal; subquadrangular anal plate following on heptagonal basals and succeeded by large interradial plate; large radials, two pentagonal and three with a short sixth side; costals 2 x 5, short, succeeded by distichals and palmars similar to Ichthyocrinus laevis; slender stem; smooth, thick joints alternating at irregular intervals with thin ones, and having slightly rounded edges and a round canal.

Found in the Rochester shale at Lockport (Hall). May also occur at Niagara.

## Class ANNELIDA Macleay

The annelids, or typical worms, are soft-bodied, marine, fresh-water or terrestrial animals, whose remains can seldom be preserved in a fossil state. It is only the tube-building order (Tubicola) that leaves any satisfactory remains. In these the tube is either a calcareous secretion of the animal or is composed of agglutinated sand and other foreign particles, being, in each case, wholly external. Worm burrows are often preserved by sand or mud infiltration, a cast of the burrow appearing in the strata.

### Genus CORNULITES Schlotheim

[Ety.: *cornu*, horn; *λίθος*, stone]

(1820. Schlotheim. *Petrefactenkunde*, p. 328)

Tube gently tapering, flexuous, the small end usually bent. The tube is either wholly or in part adherent to other objects. Walls thick, cellular, composed of imbricating rings. Surface ornamented by annulations and longitudinal striae. Interior presenting a succession of annular constrictions, giving a scalariform character to the cast.

Fig. 56 Cornulites bellistriatus

**Cornulites bellistriatus** Hall (Fig. 56) (1852. *Pal. N. Y.* 2:353, pl. 85, fig. 13-17, and v. 7, supplement, p. 20, pl. 116A, fig. 12, 13)

*Distinguishing characters.* Wall thick; annulations slightly marked at base, less strongly and irregularly marked in upper portion; fine longitudinal striae well marked throughout.

Found in the talus of Rochester shale, along the Rome, Watertown and Ogdensburg railroad above Lewiston hights.

## Class BRYOZOA Ehrenberg

The Bryozoa, or Polyzoa, are marine or fresh-water invertebrates, almost always occurring in colonies or zoaria which increase by gemmation. Each *zooid* of the colony is inclosed in a membranaceous, or calcareous, double-walled sac, the *zooecium*, into which it can withdraw. The animal possesses a mouth, an alimentary canal and an anal opening, and, in addition to these, a fringe of respiratory

tentacles—the *lophophore*. The colony is commonly attached to foreign bodies, which it either incrusts or from which it arises as an independent frond.

In the Paleozoic genera the cell apertures are often surrounded by elevated rims, or *peristomes*. In many forms a portion of the posterior wall of the tube is more or less thickened, and curved to a shorter radius, often projecting above the plane of the aperture. This forms the *lunaria*, and their ends may project into the tubes as *pseudosepta*. In the interapertural space may occur angular or irregular cells, the *mesopores*, while on many portions of the surface, tubular spines (*acanthopores*), or nodes (rounded, knob-like elevations), may occur. At intervals, in many genera, rounded elevations, or *monticules*, are found, which may, or may not, be destitute of cells. *Maculae* or irregular blotches, destitute of cells, also occur in many forms. Some species bear a superficial resemblance to certain corals, particularly the monticuliporoids.

### Genus DIPLOCLEMA Ulrich

[Ety.: διπλόος, double; κλῆμα, twig]

(1890. *Geol. sur. Illinois*, 8:368)

Zoarium dendroid, branches slightly compressed, spreading in the same plane; zooecia tubular, diverging from a wavy mesial mesotheca; apertures circular; prominent.[1]

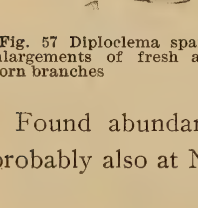


Fig. 57 Diploclema sparsa enlargements of fresh and worn branches

**Diploclema sparsa** (Hall) (Fig. 57). Trematopora sparsa Hall (1852. *Pal. N. Y.* 2:155, pl. 40A, fig. 12a-d)

*Distinguishing characters*. Slender, cylindric bifurcating stems; distant cells, opening obliquely upward; elongated nariform calicles.

Found abundantly in the Rochester shale at Lockport (Hall) probably also at Niagara.

### Genus CERAMOPORA Hall

[Ety.: κέραμος, a tile; πόρος, pore]

(1852. *Pal. N. Y.* 2:168)

Zoarium disk-like, free or attached by the center of the base; under surface with one or more layers of small, irregular cells; zooe-

[1] The generic descriptions of the Bryozoa are adapted or transcribed from Nickles & Bassler; Synopsis of American fossil Bryozoa. U. S. geol. sur. Bul. 173. I have also followed these authors in the synonomy of the species.

cia tubular, radiating on the upper surface from a depressed center; apertures oblique, imbricating, provided with a lunarium; mesopores short, irregular, decreasing in number from center to margin; large maculae or clusters of mesopores or of zooecia at regular intervals.

**Ceramopora imbricata** Hall (Fig. 58) (1852. *Pal. N. Y.* 2:169, pl. 40E, fig. 1a-i)

*Distinguishing characters.* Depressed hemispheric form, flattened or convex on the lower side; composed of cylindric or subcylindric tubes slightly diverging from the center, rectangular to plane of upper surface; arched or triangular aperture, opening on all sides toward the outer margin, arranged in alternating and imbricating series.

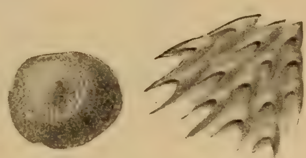


Fig. 58 Ceramopora imbricata with enlargement of surface

Found in the Rochester shale at Lockport (Hall) and probably also at Niagara.

**Ceramopora incrustans** Hall (Fig. 59) (1852. *Pal. N. Y.* 2:169, pl. 40E, fig. 2a-d)

Fig. 59 Ceramopora incrustans with enlargement of surface

*Distinguishing characters.* Incrusting habit; cells increasing unequally from a center or point of growth, short, minute, opening obliquely outward and arranged in quincunx order.

Found in the Rochester shale at Lockport (Hall); may also occur at Niagara.

## Genus CHILOTRYPA Ulrich

[Ety.: χεῖλος, lip; τρῦπα, perforation]

(1884. *Cin. soc. nat. hist. Jour.* 7:49)

Zoarium small, branching, with a narrow, irregularly contracting and expanding tube; zooecial tubes cylindric or somewhat compressed, thin walled, with or without diaphragms; walls minutely porous; apertures elliptic, oblique, the lower margin thickened and elevated; at irregular intervals maculae or monticules, composed of clusters of vesicles and of zooecia slightly larger than the average occur; interzooecial spaces occupied by vesicular tissue, which is commonly filled by a dense calcareous deposit near the surface.

**Chilotrypa ostiolata** (Hall) (Fig. 60). Trematopora ostiolata Hall (1852. *Pal. N. Y.* 2:152, pl. 40A, fig. 5a-n)

*Distinguishing characters.* Irregularly branching cylindric stems gradually tapering toward the extremities, which are obtuse; apertures about their diameter apart, arranged in spirally ascending lines or irregularly; strong peristomes; interapertural spaces smooth; stems solid or incrusting crinoids.

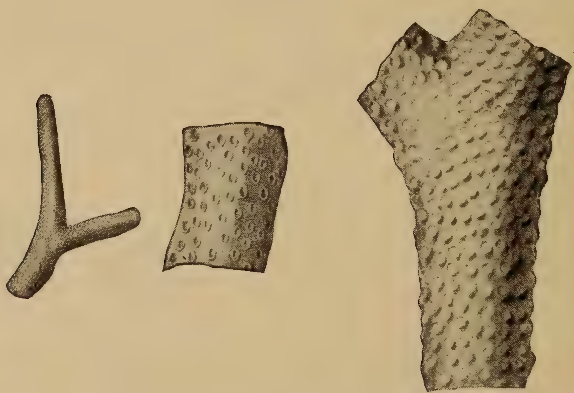


Fig. 60 Chilotrypa ostiolata; branch natural size and two enlargements

Found abundantly in the Bryozoa beds of the Rochester shale and in some of the calcareous layers below it in the Niagara sections. Also at Lockport, etc. (Hall).

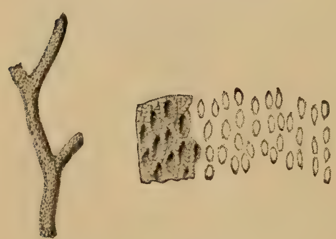


Fig 61 Batostomella granulifera with enlargement of part of surface

Genus BATOSTOMELLA Ulrich

[Ety.: βάτος, bramble; στόμα, mouth]

(1882. *Cin. soc. nat. hist. Jour.* 5:154)

Zoarium ramose, branches slender; zooecia with thick walls in the mature region and with few diaphragms in the peripheral region, often centrally perforated; apertures small, circular or oval; interspaces rounded or canaliculate, spinulose; acanthopores small and usually very numerous; mesopores small, with subcircular openings.

**Batostomella granulifera** (Hall) (Fig. 61). Trematopora granulifera Hall (1852. *Pal. N. Y.* 2:154, pl. 40A, fig. 9a-e)

*Distinguishing characters.* Slender branches; oval to elongate apertures, margined by wavy, raised, granulose lines, which are double between the cells.

Found rarely in the lower Rochester shale, associated with Ichthyocrinus and other rare fossils. Niagara sections. Also in the same shale at Lockport (Hall).

Genus LIOCLEMA Ulrich

[Ety.: λεῖος, smooth; κλῆμα, twig]

(1882. *Cin. soc. nat. hist. Jour.* 5:141, 154)

Zoarium ramose, lamellar, subglobose or incrusting; surface frequently exhibiting distinct monticules or maculae; zooecia with subcircular or irregularly petaloid apertures, separated by abundant angular mesopores, which in some species are open at the surface, in others closed; diaphragms few in the zooecia, abundant, sometimes crowded in the mesopores; acanthopores numerous and strong in the typical species, small and inconspicuous in others.

**Lioclema florida** (Hall) (Fig. 62). Callopora florida Hall (1852. *Pal. N. Y.* 2:146, pl. 40, fig. 2a-f)

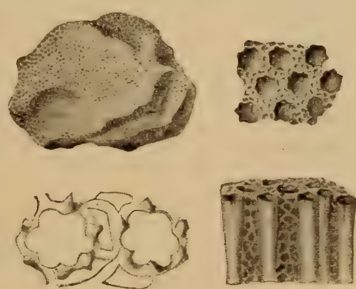


Fig. 62 Lioclema florida with side and summit views enlarged, and two calyxes much enlarged

*Distinguishing characters.* Explanate or incrusting habit; tubular cells; floriform apertures the margins of which appear as if formed of segments of six or seven smaller curves; each angle of aperture furnished with spine (acanthopore); mesopores angular in perfect specimens.

Found in the Bryozoa beds of the Rochester shales at Niagara, rare. Also at Lockport (Hall).

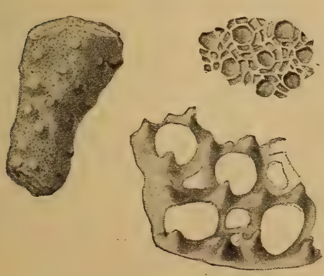


Fig. 63 Lioclema aspera with enlargements of surface

**Lioclema aspera** (Hall) (Fig. 63). Callopora aspera Hall (1852. *Pal. N. Y.* 2:147, pl. 40, fig. 4a-i)

*Distinguishing characters.* Stems solid or hollow cylinders, often also incrusting other bodies in broad, explanate or foliate expansions; clavate or thickened extremities of stems; circular or slightly oval apertures; finely reticulated interspaces; margins of apertures surrounded by minute points (acantho-

pores) which give the entire surface an asperato-granular appearance.

Found in the Rochester shale at Lockport (Hall), and probably also at Niagara.

Genus BYTHOPORA Miller & Dyer

[Ety.: βυθός, depth; πόρος, pore]

(1878. *Contrib. to paleontology* no. 2, p. 6)

Fig. 64. Bythopora spinulosa enlarged

Zoarium usually with slender branches, sometimes of considerable size; diaphragms obsolete; apertures oblique, narrowing above; interspaces canaliculate; mesopores few; acanthopores strong, rarely more than one to each zoarium, sometimes wanting.

**Bythopora spinulosa** (Hall) (Fig. 64). *Trematopora spinulosa* Hall (*Pal. N. Y.* 2:155, pl. 40A)

*Distinguishing characters.* Oval apertures; cylindrical branches; strong spines (acanthopores) arranged at nearly regular intervals.

Found in the Rochester shale at Lockport. (Hall) Probably occurs also at Niagara.

Genus TREMATOPORA Hall

[Ety.: τρῆμα, foramen; πόρος, pore]

(1852. *Pal. N. Y.* 2:149)

Zoarium ramose; surface smooth or with monticules; zooecia thin-walled, the contact lines of walls of adjoining zooecia distinct; diaphragms few, in the proximal ends of the zooecia; apertures circular or oval, with a more or less well marked peristome; interspaces solid; mesopores irregularly angular, often obscurely moniliform, with diaphragms at the constricted parts; acanthopores of medium or small size usually present.

**Trematopora tuberculosa** Hall (Fig. 65) (1852. *Pal. N. Y.* 2:149, pl. 40A, fig. 1a-g)

Fig. 65 Trematopora tuberculosa with enlargement of surface

*Distinguishing characters.* Irregularly ramose and stout branches; tuberculous monticules; tubular cells with oval apertures and thin elevated calicle or margin which is spinulose (bearing acanthopores); interapertural spaces solid, but septate below.

Found abundantly in the Bryozoa beds of the Rochester shales, at Niagara, also at Lockport (Hall).

**Trematopora (?) striata** Hall (Fig. 66) (1852. *Pal. N. Y.* 2:153, pl. 40A, fig. 7a-d and 8a-b)

*Distinguishing characters.* Expanded at the base; strongly striated; slender, cylindric, scarcely tapering branches; oblong oval apertures distant from each other about the width of the aperture; interapertural space with continuous groove.

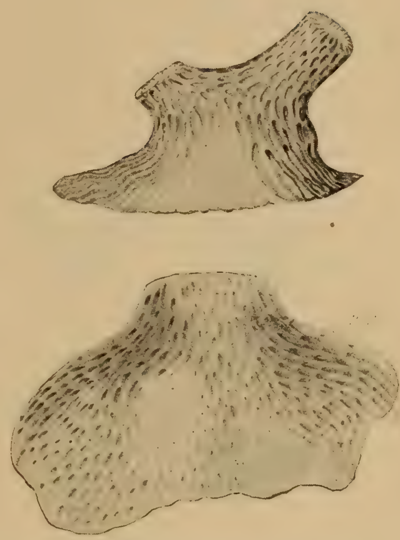


Fig. 66 Trematopora (?) striata much enlarged

Found in the Rochester shale at Lockport (Hall), probably also at Niagara.

### Genus CALLOPORA Hall

(emend. Ulrich)

[Ety.: κάλλος, beauty; πόρος, pore]

(1852. *Pal. N. Y.* 2:144)

Zoarium usually ramose, the branches frequently anastomosing and forming bushy clumps; zooecia at first prismatic, four to eight sided, gradually becoming cylindric in most cases; at first with closely set diaphragms, becoming more distant, finally in the mature region usually closely set; apertures closed at times by perforated, often ornamental covers; mesopores more or less numerous, angular, crowded with diaphragms. No acanthopores.

**Callopora elegantula** Hall (Fig. 67) (1852. *Pal. N. Y.* 2:144, pl. 40, fig. 1a-m)

*Distinguishing characters.* Cespitose or fruticulose groups of small stems frequently branching; branches bifurcating or variously diverging from the stem; solid; extremities often hollow or cup-like indentations, also blunt; apertures circular, the opercula or covers

with a central perforation from which radiate a number of ridges, giving the cells often a radiately septate appearance; mesopores single, in groups or encircling the apertures.

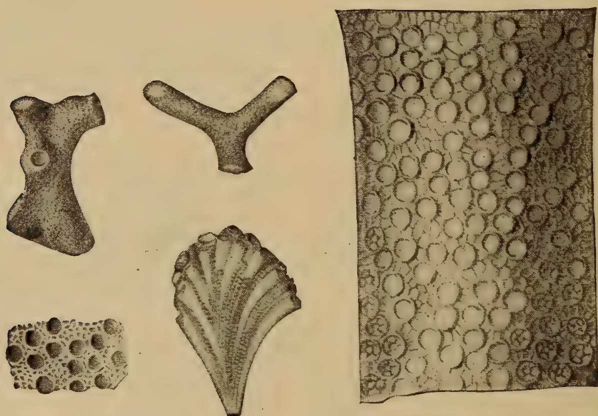


Fig. 67 Callopora elegantula with enlargements of surface, and individual tubes

Found abundantly in the Bryozoa beds of the Rochester shale at Niagara. Also common at Lockport (Hall).

Genus PHYLLOPORINA Ulrich

[Ety.: φύλλον, leaf; πόρος, pore]

(1890. *Geol. sur. Illinois*, 8:399, 639)

Zoarium branching, with branches irregularly anastomosing, with two to eight rows of apertures on one side, longitudinally striated

Fig. 68 Phylloporina asperato-striata with enlargement of celluliferous and non-celluliferous faces, the latter showing the asperate-striate character

on the other; zooecia more or less tubular, often with diaphragms, and generally separated by tabulated interstitial spaces, which are closed at the surface; acanthopores often present.

**Phylloporina asperato-striata** (Hall) (Fig. 68). Retepora asperato-striata Hall (1852. *Pal. N. Y.* 2:161, pl. 40C, fig. 2a-h)

*Distinguishing characters.* Network of anastomosing branches, with oval interstices which are somewhat unequal; outer face roughly striate; inner face poriferous; three, four or more rows of oval or subangular cells arranged somewhat in oblique parallel lines or in quincunx order; apertures in perfect specimens probably with peristomes.

Found abundantly in the Bryozoa beds of the Rochester shale at Niagara. Generally adhering to the shale laminae by the celluliferous face. Also at Lockport (Hall).

Genus DRYMOTRYPA Ulrich

[Ety.: δρῦμός, coppice; τρῦπα, perforation]

(1890. *Geol. sur. Illinois.* 8:399)

Zoarium branching dichotomously at frequent intervals; zooecia in several ranges, tubular, opening on one side only and springing from a thin double plate, beneath which a number of vesicles are

**Fig. 69 Drymotrypa diffusa with celluliferous and non-celluliferous sides enlarged**

present; reverse side longitudinally striated; vestibules expanding from the orifices to the angular apertures.

**Drymotrypa diffusa** (Hall) (Fig. 69) Retepora diffusa Hall (1852. *Pal. N. Y.* 2:160, pl. 40C, fig. 1a-f)

*Distinguishing characters.* Shrubby form, several stems originating from a common base; stems frequently bifurcating and spreading laterally, forming a broad frond; stems and branches cellulifer-

ous on one side only, deeply striated longitudinally on the other; quadrangular or subrhomboidal apertures; branches often thickened or clavate, always obtuse.

Found in the upper part of the lower Rochester shale and the Bryozoa beds at Niagara. Rare. Also at Lockport (Hall).

Genus FENESTELLA Lonsdale

[Ety.: *fenestella*, a little window]

(1839. Murchison. *Silurian system*, p. 677)

Zoarium consisting of a calcareous branching frond, forming cup-shaped or funnel-shaped expansions. The branches fork, and are connected by transverse bars or dissepiments, thus inclosing spaces or fenestrules. The cell apertures occur only on the inner side of

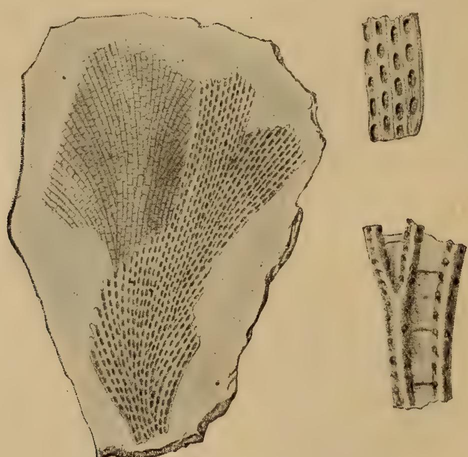


Fig. 70 Fenestella elegans with enlargements

the branches. They are surrounded by rims or peristomes and are arranged in two parallel rows, while between them occurs a ridge (carina) or a row of nodes.

**Fenestella elegans** Hall (Fig. 70) (1852. *Pal. N. Y.* 2:164, pl. 40D, fig. 1a-g)

*Distinguishing characters.* Carina subdued; apertures with their longer diameter oblique to the direction of the branches; branches slender, frequently bifurcating; thin and slender dissepiments scarcely enlarging at the junction with the branches; fenestrules on

non-celluliferous side oblong, quadrangular, rarely oval; branches finely striate.

Found in the Bryozoa bed of the Rochester shale at Niagara. Also in the same rock at Lockport and elsewhere (Hall).

Genus SEMICOSCINIUM Prout

[Ety.: *semi*, half (somewhat like); κόσκινον, sieve; Coscinium, a genus of Bryozoa]

(1859. *St Louis acad. sci. Trans.* 1:443)

Zoarium funnel-shaped, celluliferous on the outer side; dissepiments wide, very short, the branches appearing to anastomose on the non-poriferous face, where the fenestrules are subrhomboidal or rounded. Apertures in two rows, with a very high median keel, which is expanded at the summit.

**Semicoscinium tenuiceps** (Hall) (Fig. 71, 72). Fenestella tenuiceps Hall (1852. *Pal. N. Y.* 2:165, pl. 40D, fig. 2a-h) Fenestella prisca? Hall (1852. *Pal. N. Y.* 2:50, pl. 19, fig. 4a-m)

*Distinguishing characters.* Carina sharp and thin; transverse dissepiments not extending as high as the branches, sometimes scarcely

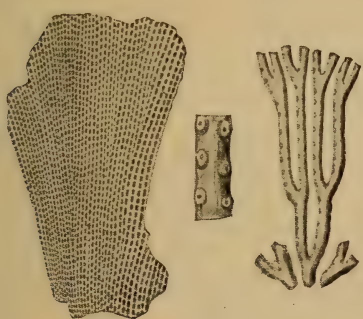


Fig. 71 Semicoscinium tenuiceps, Clinton. With enlargements

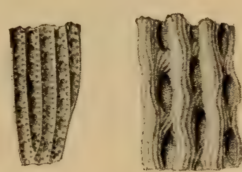


Fig. 72 Semicoscinium tenuiceps, Niagara. Enlargements of celluliferous and non-celluliferous faces

visible; round large apertures opening laterally so as to be scarcely visible when looking down on the frond; non-celluliferous side with oval fenestrules, branches on non-celluliferous side striate, appearing granular when worn.

Found in the Bryozoa beds of the Rochester shales at Niagara; also at Lockport (Hall) (?). It also occurs in the Clinton beds at Lockport, and probably also at Niagara.

## Genus POLYPORA McCoy

[Ety.: πολύς, many; πόρος, pore]

(1845. *Synopsis Carbon. foss. Ireland*, p. 206)

Zoarium as in Fenestella, but with from two to eight rows of zooecia on a branch, and without median keel, but sometimes with a row of strong nodes or tubercles.

**Polypora incepta** Hall (Fig. 73) (1852. *Pal. N. Y.* 2:167, pl. 40D, fig. 5a-f)

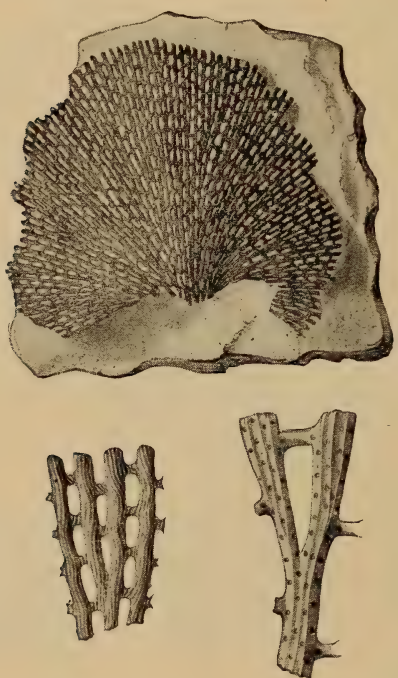


Fig. 73 Polypora incepta with non-celluliferous and celluliferous faces enlarged

*Distinguishing characters.* Funnel-shaped, but generally compressed form; branches dividing somewhat regularly, sometimes anastomosing; dissepiments at regular intervals, slender, scarcely thickened at their junction with branches; fenestrules oblong, quadrangular, rarely oval; non-celluliferous face longitudinally striate; three or four rows of cell apertures, oval and alternating; dissepiments thinner on celluliferous than on non-celluliferous face; sometimes expanding at the junction with the branches; non-celluliferous face indistinguishable from Fenestella.

Found abundantly in the Bryozoa beds of the Rochester shale at Niagara, and the talus of the cliff above Lewiston hights. Also in the shale at Lockport (Hall).

## Genus HELOPORA Hall

[Ety.: ἧλος, nail; πόρος, pore]

(1852. *Pal. N. Y.* 2:44)

Zoarium bushy, dichotomously branching, the whole consisting of numerous slender, equal segments, united by terminal articula-

tions; zooecia subtubular, more or less oblique, radially arranged about a central axis and opening on all sides of the segments.

**Helopora fragilis** Hall (Fig. 74) (1852. *Pal. N. Y.* 2:44, pl. 18, fig. 3a-f)

*Distinguishing characters.* Minute cylindric or clavate zoarium swollen at one end; oval or subangular pores, having a spiral direction around the stipe and arranged between longitudinal elevated lines.

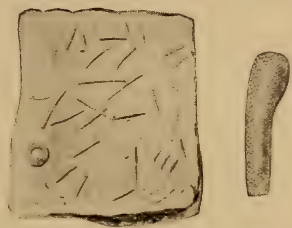


Fig. 74 Helopora fragilis natural size and enlarged

Found in the Clinton beds at Lockport etc. (Hall). Probably occurs also at Niagara. Also abundant in the thin calcareous upper Medina layers at Niagara (?).

Genus CLATHROPORA Hall

[Ety.: *clathri*, a lattice; *porus*, a pore]

Zoarium composed of anastomosing branches, forming a regular network with round or oval spaces or fenestrules, with a pointed,

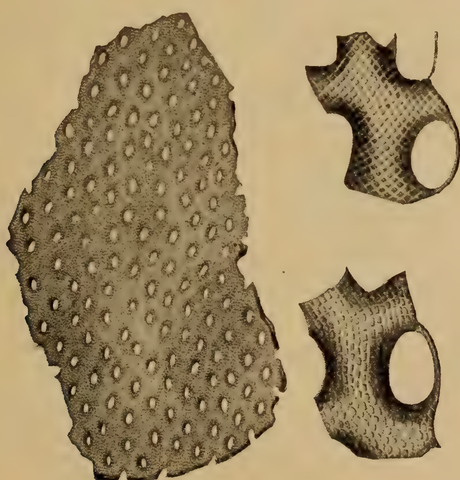


Fig. 75 Clathropora frondosa with portions of celluliferous face enlarged

articulating base; the branches are made up of two layers grown together back to back, and with the zooecial tubes opening on both sides of the frond; apertures usually subquadrate, arranged longitudinally.

**Clathropora frondosa** Hall (Fig. 75) (1852. *Pal. N. Y.* 2:160, pl. 40B, fig. 5a-e)

*Distinguishing characters.* Reticulate, expanded, flabellate or funnel-shaped frond, both surfaces regularly and equally celluliferous; apertures rhomboidal or oblong quadrangular, opening obliquely upward.

Found in the Rochester shale at Lockport (Hall) and probably also at Niagara.

**Clathropora alcicornis** Hall (Fig. 76) (1852. *Pal. N. Y.* 2:159, pl. 40B, fig. 4a-c)

*Distinguishing characters.* Cylindric branches, bifurcating and variously branched; entire surface celluliferous; apertures quad-

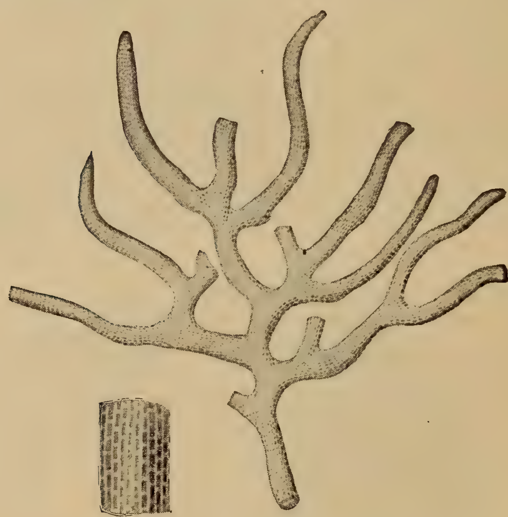


Fig. 76 Clathropora alcicornis with enlargement

rangular, rhomboidal or oblong and variable in form at the division of the stem.

Found in the lower Rochester shale up to and in the Bryozoa bed at Niagara. Rare. Also at Lockport (Hall).

Genus RHINOPORA Hall

[Ety.: ῥινός, hide; πόρος, pore]

(1852. *Pal. N. Y.* 2:48)

Zoarium forming large, undulating bifoliate expansions, celluliferous on both sides; surface usually smooth, rarely with solid

monticules, and traversed by slender, rounded, bifurcating ridges, which appear as shallow grooves when the surface is worn; apertures nearly circular, occupying the summits of prominent papillae; mesopores present, but closed at the surface: large median tubuli in the middle layer or *mesotheca*.

**Rhinopora tuberculosa** Hall (Fig. 77) (1852. *Pal. N. Y.* 2:170, pl. 40E, fig. 4a-c)

*Distinguishing characters.* Lamellose or explanate palmate fronds; asperate and tuberculous surface; tubercles mostly destitute of cells at the summit; cells rising in pustules on the surface and opening by roundish oval or tripetalous apertures.

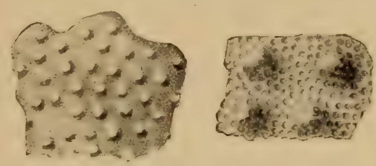


Fig. 77 Rhinopora tubercolosa with enlargement

Found in the Rochester shale at Lockport (Hall) and probably also at Niagara.

Genus DIAMESOPORA Hall

[Ety.: διά, through; μέσος, middle; πόρος, pore]

(1852. *Pal. N. Y.* 2:158)

Zoarium ramose, of hollow stems lined internally by an epitheca; zooecia simple, hexagonal, or rhomboidal, with an oval orifice in the anterior half, which, with growth, forms a tubular vestibule; aperture with peristomes equally elevated or highest posteriorly; intervestibular spaces compact or horizontally laminated.

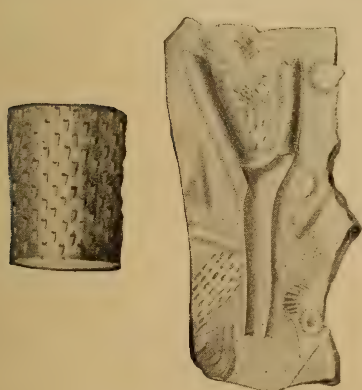


Fig. 78 Diamesopora dichotoma with enlargement

**Diamesopora dichotoma** Hall (Fig. 78) (1852. *Pal. N. Y.* 2:158, pl. 40B, fig. 3a-d)

*Distinguishing characters.* Cylindric, hollow, regularly bifurcating stems (a thin crust inclosing inorganic matter); interior of hollow branches transversely striate; cells opening upward in regular ascending or spiral lines; prominent nariform peristomes; stems usually flattened.

Found in the Bryozoa beds of the Rochester shales at Niagara, usually in a crushed condition. Also at Lockport (Hall).

Genus LICHENALIA Hall

[Ety.: λειχήν, lichen]

(1852. *Pal. N. Y.* 2:171)

Zoarium a subcircular expansion, consisting of a single lamina, but often growing in successive layers, the one over the other; zooecia prostrate, elongate subrhomboidal, with a direct, subtubular, outward prolongation or vestibule; apertures rounded, with the peristome much elevated on the posterior side; interspaces depressed.

**Lichenalia concentrica** Hall (Fig. 79) (1852. *Pal. N. Y.* 2:171, pl. 37A, fig. 2a, b)

*Distinguishing characters.* Circular frond, slightly cup-form in the young state, flattened at maturity; generally variously contorted from irregular growth or accident, and thick at intervals; concen-

Fig. 79 Lichenalia concentrica

trically striate and rugose surface, strongest on non-celluliferous side; apertures in concentric lines, narrow, opening on the summit of an elevated pustule.

Found rarely in the lower Clinton limestone; abundantly in the Clinton lenses; and again rarely in the lower Rochester shale and the Bryozoa bed. Niagara sections. Also at Lockport and elsewhere (Hall).

## Class BRACHIOPODA Cuvier

The Brachiopoda are marine animals, sparingly represented in modern seas, but most prolific in the Paleozoic and early Mesozoic waters.

The valves of the brachiopod shell are dorsal and ventral, and not right and left as in the lamellibranch Mollusca; they are unequal, and each is symmetric with reference to a median line (longitudinal axis) drawn through its apex. The larger valve may have its beak truncated or furnished with an opening or *foramen*, for the emission of the fleshy *pedicle*, by means of which the animal fixes itself to rocks, shells or other substances.

Certain genera, such as Crania, do not conform to this mode of fixation, but cement their shell directly to the foreign object, while others, e. g. Pholidops, appear to have led a free existence. In many of the discinoid genera, such as Orbiculoidea, the pedicle passed through an opening in the lower valve; while in Lingula it protruded between the two very nearly equal valves. In all cases the valve giving emission to the pedicle is spoken of as the *pedicle valve*.

The opposite valve in the more specialized genera bears on its interior two short processes, or *crura*, which arise from the hinge

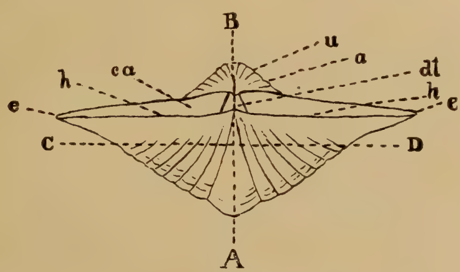



Fig. 80 Diagram of Spirifer. (AB) Longitudinal axis marking the hight; (CD) Transverse axis marking the width; (a) Anterior (front) end; (B) posterior (beak) end; (h) hinge line; (ca) cardina ar a; (e) cardinal extremities; (dt) deltidium; (u) umbo; (a) apex or beak

plate. To these may be attached a calcareous *brachidium*, which functions as a support for the delicate fleshy "arms". In a large number of forms this brachidium is absent, and the fleshy arms are directly supported by the crura, but their relation to the valve in question is similar to that obtaining in the brachidium-bearing forms. This valve is designated the *brachial* valve. In all the forms in which the valves are articulated with each other (Brachiopoda articulata) such articulation is produced by *teeth* arising from the pedicle valve and lodged in *sockets* in the brachial valve. The beak of the brachial valve is commonly furnished with a more or less pronounced *cardinal process*, which, at its

free end, presents a surface for the attachment of the *diductor*, or opening muscles, the opposite ends of which are attached near the center of the pedicle valve, where they often leave pronounced *scars*. A contraction of these muscles pulls on the cardinal process, and draws the beak of the brachial valve toward the interior of the pedicle valve, and thus opens the valves. *Adductor* muscles passing from valve to valve and also commonly leaving scars, close the valves again. Below the cardinal process and often merged with it, is an elevated hinge plate whose surface often serves for muscular attachment.

Beneath the beak of each valve frequently occurs a flat " cardinal area ", bounded above by the *cardinal slopes* and below by the articulating margin or *hinge line*. This area is commonly divided in the center by a triangular fissure (*delthyrium*). It may be covered either by a single plate (*deltidium*) or by two plates which join in the center (*deltidial plates*).

The important surface features of the shell are: the *lines of growth*, the radiating *plications* or *striations*, the *fold* or medial elevation, and the *sinus* or medial depression, the fold commonly occurring on the brachial, and the sinus on the pedicle valve.

## Genus LINGULA Bruguière

[Ety.: *lingula*, little tongue]

(1789. *Hist. nat. des vers testacés;* 1892. *Pal. N. Y.* v. 8, pt 1, p. 2)

Shell with the valves nearly equal and varying in outline from elongate ovate to subtriangular, always longer than wide; valves arched. Animal attached by a long muscular pedicle which protrudes from between the beaks of the two valves.

Fig. 81 Lingula cuneata enlarged x 2

**Lingula cuneata** Conrad (Fig. 81)
(Hall. 1852. *Pal. N. Y.* 2:8, pl. 4)

*Distinguishing characters.* Acutely cuneate form; very acute beak with nearly rectilinear margins; slightly curved base; valves convex near the beak, flatter toward front; fine longitudinal striae.

Found in the upper Medina sandstones at Niagara. Also at Lockport etc. (Hall).

Genus PHOLIDOPS Hall

[Ety.: φολίς, a scale]

(1859. *Pal. N. Y.* 3:489; 1892. *Pal. N. Y.* v. 8, pt 1, p. 155)

Shells small, with equal valves, patella-like in outline; inarticulate and unattached, without pedicle opening; position of apex variable; edges of valves flattened where they meet, and on the interior are elevated areas for attachment of muscles, etc. In molds of the interior, a strongly marked impression of this callosity appears.

**Pholidops squamiformis** Hall (Fig. 82). Orbicula ? squamiformis Hall (1852. *Pal. N. Y.* 2:250, pl. 53, fig. 4a-b)

*Distinguishing characters.* Depressed oval form; squamous concentric striae, most marked on anterior slope.

Fig. 82 Pholidops squamiformis natural size and enlarged

Found near the middle of the lower Rochester shales at Niagara. Also at Lockport (Hall).

Genus DICTYONELLA Hall

[Ety.: δίκτυον, net]

(1867. *N. Y. state cab. nat. hist. 20th an. rep't*, p. 274; 1893. *Pal. N. Y.* v. 8, pt 2, p. 307)

Shell subtriangular in outline with biconvex valves, pedicle valve having a broad median sinus, and brachial valve a corresponding fold; beak of pedicle valve acute and arched over that of brachial valve, though not closely appressed against it; a short, triangular deltidium depressed within the cavity of the pedicle valve; teeth long, marginal and ridge-like on the diverging cardinal slopes and fitting into narrow marginal grooves on the brachial valve; brachial valve with a strong median septum. Exterior covered by a coarse network of superficial cells, usually hexagonal, sometimes circular in outline. A triangular area at the umbo of the pedicle valve is destitute of this reticulation.

**Dictyonella corallifera** Hall (Fig. 83). Atrypa corallifera Hall (1852. *Pal. N. Y.* 2:281, pl. 58, fig. 5a-t)

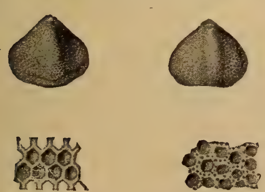


Fig. 83 Dictyonella corallifera with surface enlarged

*Distinguishing characters.* Form rhomboidal to subtriangular, base often nearly straight; broad and strong sinus and fold; reticulated or pitted surface, the space between the pits often punctate.

Found in the Bryozoa beds of the Rochester shale at Niagara. Also at Lockport (Hall).

## Genus LEPTAENA Dalman

[Ety.: λεπτός, thin]

(1828. *Kongl. Svenska Vet. Akad. Handl.* p. 93,94)

Shells concavo-convex; surface covered by conspicuous concentric corrugations or wrinkles over the flatter portions of the valves. Where these cease, the surface is more or less abruptly deflected, forming a conspicuous anterior slope. Whole exterior covered with fine, radiating, tubular striae, which in well preserved specimens are crenulated by finer concentric striae. Hinge line straight; cardinal area narrow. A convex deltidium present, perforated at the apex by a foramen, which often encroaches on the apex of the valve. A trilobed cardinal process and well defined muscular impressions are present.

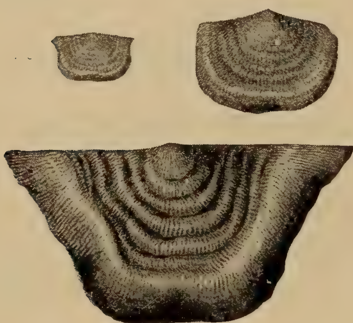


Fig. 84 Leptaena rhomboidalis

**Leptaena rhomboidalis** (Wahlenberg) (Fig. 84). Leptaena depressa Hall (1852. *Pal. N. Y.* 2:257, pl. 53, fig. 6a-l)

*Distinguishing characters.* Corrugated part gently convex to slightly concave; abrupt anterior deflection; strong concentric corrugations and fine striae. Narrow hinge area.

Found in the upper Clinton limestone, the Clinton lenses, and the lower Rochester shale up to and in the Bryozoa bed. Rarely above this. Also at Lockport and elsewhere (Hall).

## Genus STROPHEODONTA Hall

[Ety.: στροφή, bend; ὀδούς, tooth]

(1852. *Pal. N. Y.* 2:63. Hall & Clarke, 1892; *Pal. N. Y.* v. 8, pt 1, p. 284)

Shell normally concavo-convex; hinge line usually equal to or greater than the greatest width of the shell. Area of the pedicle valve higher than that of the brachial valve, both furnished with projecting denticulations, which interlock and form articulations. Muscular areas well marked and variously bounded. A strongly marked bifid cardinal process occurs in the brachial valve.

**Stropheodonta corrugata** (Conrad) (Fig. 85) (Hall. 1852. *Pal. N. Y.* 2:59, pl. 21)

*Distinguishing characters.* Semioval, nearly flat; small, acute lateral extensions of hinge; fine, prominent striae sometimes bifurcating or alternating with finer ones; oblique folds on hinge margin.

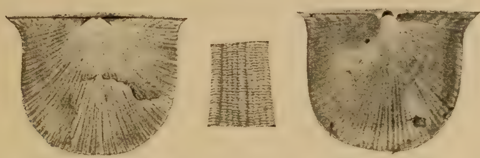


Fig. 85 Stropheodonta corrugata; with surface enlarged

Found in the Clinton limestone (?) and the Clinton lenses at Niagara. Rare.

**Stropheodonta profunda** Hall (Fig. 86) (1852. *Pal. N. Y.* 2:61, pl 21)

*Distinguishing characters.* Large, semioval, much wider than high; auriculate hinge; profoundly concave brachial valve; abruptly deflected margins; fine, unequal surface striae; papillose or punctate interior.

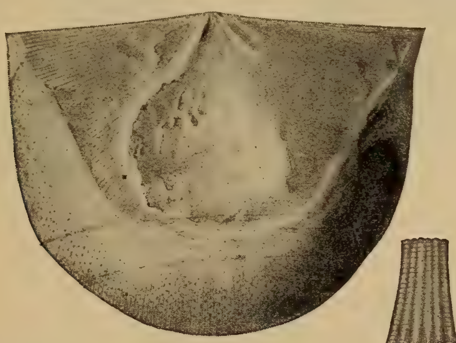


Fig. 86 Stropheodonta profunda with enlargement of striae

Found in the lower and upper Clinton limestone at Niagara. Also in the latter bed at Lockport (Hall).

Genus STROPHONELLA Hall

[Ety.: στρόφος, turned around]

(1879. *N. Y. state mus. nat. hist., 26th an. rep't*, p. 153; Hall & Clarke. 1892. *Pal. N. Y.* v. 8, pt 1, p. 290)

Shells with the form and structure of Stropheodonta, but with the relative convexity of the valves reversed.

**Strophonella striata** Hall (Fig. 87) Leptaena striata Hall (1852. *Pal. N. Y.* 2:259, pl. 53, fig. 7)

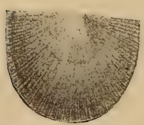


Fig. 87 Strophonella striata

*Distinguishing characters.* Semielliptic, almost flat, hinge line equal to or a little longer than width of shell; fine, rounded, radiating surface striae, which increase by implantation; fine concentric striae.

Found in the middle and upper Rochester shale at Niagara.

**Strophonella (?) patenta** Hall (Fig. 88). Leptaena patenta Hall (1852. *Pal. N. Y.* 2:60, pl. 21)

*Distinguishing characters.* Wider than high; hinge not auriculate;

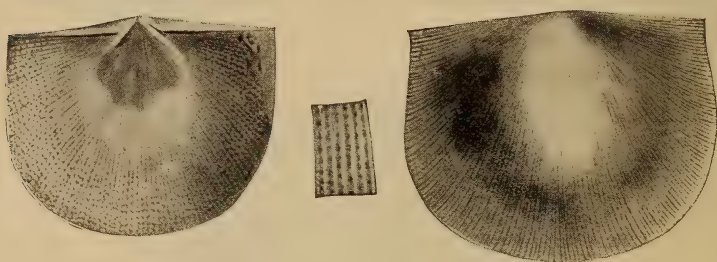


Fig. 88 Strophonella (?) patenta with enlarged surface features

fine unequal radii crossed by finer concentric striae; inner surfaces of valves thickly covered with sharp points.

Found in the Clinton limestones and lenses and doubtfully in the middle Rochester shales at Niagara.

Genus PLECTAMBONITES Pander

[Ety.: πλεκτός, plaited; ἄμβων, beak]

(1830. *Beiträge zur Geognosie des Russ. Reiches.* p. 90. Hall & Clarke, 1892; *Pal. N. Y.* v. 8, pt 1, p. 236, 295)

Shells small, concavo-convex; surface striae very fine, often alternating in size; hinge line making greatest width, extremities often

subauriculate; cardinal areas narrow, sometimes obscurely crenulated on the margins. Delthyrium partially closed by convex plate, but mostly occupied by cardinal process of opposite valve. Cardinal process appears trilobate. Muscular areas moderately well defined.

**Plectambonites sericea** (Sowerby) (Fig. 89). Leptaena sericea Hall (1852. *Pal. N. Y.* 2:59, pl. 21)


Fig. 89 Plectambonites sericea

*Distinguishing characters.* Outline semicircular to semioval; hinge line extended, ending in acute points; striae strong, elevated, alternating with finer ones.

Found in the lower Clinton limestone at Niagara. Rare.

**Plectambonites transversalis** (Wahlenberg) (Fig. 90). Leptaena transversalis Hall (1852. *Pal. N. Y.* 2:256, pl. 53, fig. 5a-b)

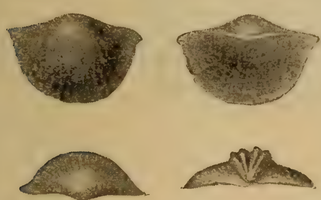


Fig. 90 Plectambonites transversalis

*Distinguishing characters.* Outline semicircular; strongly convex pedicle, and extremely concave brachial valve, conforming to each other; strongly incurved beak of pedicle valve, which causes an inflection of the hinge line; hinge line produced; fine distant elevated striae with extremely fine striae between; strongly punctate character of exfoliated portions.

Found in the Clinton lenses, and abundantly in the lower Rochester shale at Niagara. Also at Lockport (Hall).

Genus ORTHOTHETES Fischer de Waldheim

[Ety.: ὀρθός, straight]

(1830. *Soc. imp. natural. d. Moscow Bul.* 1:375. Hall & Clarke, 1892; *Pal. N. Y.* v. 8, pt 1, p. 253)

Shell varying from plano-convex to biconvex, sometimes becoming concavo-convex with age. Pedicle valve most convex about the beak, which often tends toward irregular growth; cardinal area well developed, with a thick, more or less convex deltidium. Teeth not supported by dental plates. Brachial valve most convex near

the middle, with a narrow hinge area; cardinal process quadrilobate as seen from above. Surface covered by slender radiating striae, which are crenulated by concentric lines.

**Orthothetes subplanus** (Conrad) (Fig. 91). Leptaena subplana Hall (1852. *Pal. N. Y.* 2:259, pl. 53, fig. 8-10)

*Distinguishing characters.* Pedicle valve at first convex, later becoming concave; valves nearly equal in length and width; extended hinge line, sometimes projecting into points; sharp angular or subangular to rounded striae, sometimes bifurcating before reaching

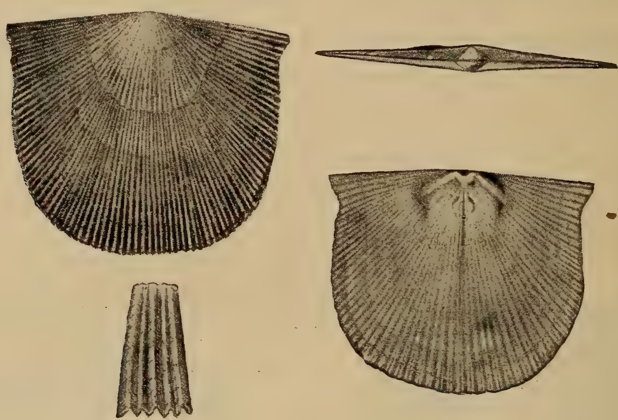


Fig. 91 Orthothetes subplanus

margin, separated by wider interspaces; the usual method of increase is by intercalation of fine striae, which soon grow to strength of the chief ones; fine concentric and occasionally coarser lines of growth.

Found at Niagara in the upper Clinton beds and the Clinton lenses; also abundantly in certain thin calcareous layers of the lower Rochester shale, less common in the middle and upper shale. Also at Lockport and elsewhere (Hall).

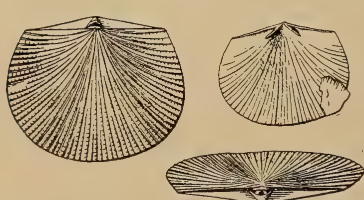


Fig. 92 Orthothetes hydraulicus

**Orthothetes hydraulicus** (Whitfield) (Fig. 92) (Grabau. *Geol. soc. Am. Bul.* 11:365, pl. 22)

*Distinguishing characters.* Small size; obtuse cardinal margins with hinge line shorter than greatest width of shell; uniformly rounded front; strong rounded, sharply de-

fined radiating striae, which curve slightly upward on the lateral margins near the cardinal area; strongest striae reaching to beak; increase by repeated intercalation; fine concentric striae.

Found in great abundance in the Manlius limestone of North Buffalo, etc., usually in the condition of molds.

### Genus CHONETES Fischer de Waldheim

[Ety.: χώνη, funnel]

(1837. *Oryctographie du gouv. de Moscow*, pt 2, p. 134; 1892. *Pal. N. Y.* v. 8, pt 1, p. 303)

Shells concavo-convex (in our species), with the pedicle valve convex; hinge line straight, making the greatest diameter of the shell; areas narrow; the triangular opening (delthyrium) in the area of the pedicle valve covered by a convex deltidium. Upper margin of area bears a single row of hollow spines. Area of brachial valve without spines; cardinal process appearing quadrilobate. Interior of shell strongly papillose in the pallial region. A low median ridge divides the muscular area of the pedicle valve. A similar ridge occurs in the brachial valve. External surface usually covered by radiating striae.

**Chonetes cornutus** (Hall) (Fig. 93) (1852. *Pal. N. Y.* 2:64, pl. 21)

*Distinguishing characters.* Semicircular; fine equal striae, round, straight and bifurcating with similar interspaces; three cardinal spines on each side of beak, obliquely diverging below, curving inward at middle and upper parts; outer one longest.

Fig. 93 Chonetes cornutus natural size and enlarged

Found (doubtfully) in the Lockport limestone at Niagara.

### Genus ORTHIS Dalman

(*sensu strictu*)

[Ety.: ὀρθός, straight; in allusion to hinge line]

(1828. *Kongl. Svenska Vet. Akad. Handl.* p. 93, 96. Hall & Clarke 1892; *Pal. N. Y.* v. 8, pt 1, p. 192)

Shells plano-convex in contour; costae strong, sharp and comparatively few, rarely if ever bifurcating; cardinal area of pedicle

valve elevated and somewhat incurved; dental lamellae slightly developed, not extending the entire length of the umbonal cavity. Cardinal process an elongate vertical plate, logitudinally dividing the deep deltidial cavity.

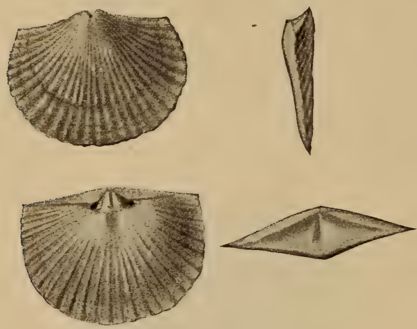


Fig. 94 Orthis flabellites

**Orthis flabellites** Foerste (Fig. 94). Orthis flabellulum var. Hall (1852. *Pal. N. Y.* 2:254, pl. 52)

*Distinguishing characters.* Long hinge line; semioval form; coarse, simple rounded plications, equal to spaces between them; marked concentric growth lines.

Found in the upper Clinton limestone and the lower Rochester shale at Niagara. Rare. Also in the shale at Lockport (Hall).

**Orthis (?) punctostriata** Hall (Fig. 95) (1852. *Pal. N. Y.* 2:254, pl. 52, fig. 5a-f)

Fig. 95 Orthis (?) punctostriata with enlargement of surface

*Distinguishing characters.* Subglobose contour, nearly equal, extremely convex valves; beak of pedicle valve somewhat longer than that of brachial valve, but both prominent; short hinge line, still shorter but high area; fine equal bifurcating striae; extremely fine concentric striae; punctate interspaces.

Found in the talus of Rochester shale above Lewiston hights. Rare. Also in the shale at Lockport (Hall).

## Genus ORTHOSTROPHIA Hall

[Ety.: the name refers to the relations of the genus to Orthis and Stropheodonta]

(1883. *N. Y. state geol. 2d an. rep't,* pl. 36; 1892. *Pal. N. Y.* v. 8, pt 1, p. 199, 223, 253)

Shells with convexity of valves reversed; surface finely plicated; deep narrow muscular area; cardinal process elongate and simple.

**Orthostrophia (?) fasciata** Hall (Fig. 96). Orthis fasciata Hall (1852. *Pal. N. Y.* 2:255, pl. 52)

Fig. 96 Orthostrophia (?) fasciata

*Distinguishing characters.* Semi-oval contour; produced hinge line; clustered or fasciculated striae almost simple at their origin, dividing toward the margin.

Found in the lower Rochester shale at Niagara (?). Also at Lockport (Hall).

Genus DALMANELLA Hall & Clarke

[Ety.: proper name]

(1892. *Pal. N. Y.* v. 8, pt 1, p. 205, 223)

Shells plano-convex or subequally biconvex; pedicle valve usually the deeper, often elevated at the umbo and arched over the cardinal area; hinge line generally shorter than the greatest width of the shell; surface finely striate. Prominent teeth supported by lamellae which circumscribe the muscular area; cardinal process tri- to quadrilobed, continued downward in a median ridge dividing a quadriplicate muscular area.

**Dalmanella elegantula** (Dalman) (Fig. 97). Orthis elegantula Dalman (Hall 1852. *Pal. N. Y.* 2:252, pl. 52, fig. 3a-r)

Fig. 97 Dalmanella elegantula

*Distinguishing characters.* Strongly convex pedicle valve with high but narrow area and incurved beak; nearly flat brachial valve; generally with a longitudinal concavity in the center; fine close set striae, which divide dichotomously toward the margin; extremely fine concentric lines and coarser growth lines.

Found in the Clinton lenses, and abundantly at intervals in the lower and middle (Bryozoa beds) Rochester shales at Niagara. Also at Lockport and elsewhere (Hall).

## Genus RHIPIDOMELLA Oehlert

[Ety.: ῥιπίς, fan]

(1891. *Journal de conchyliologie.*, p. 372; 1892. *Pal. N. Y.* v. 8, pt 1, p. 209)

Shell almost circular in outline; both valves gently convex; hinge area short; slight median depression in each valve. Surface covered with fine, rounded, hollow, tubular striae, which frequently open on the surface. On the interior of the pedicle valve are two strong diverging teeth. Muscular area large, and deeply impressed, consisting of fluted diductor impressions, inclosing small central adductors. The pedicle scar fills the cavity of the beak. The interior of the brachial valve shows deep and narrow dental sockets, with prominent projecting crural plates. In the center is a strong cardinal process, below which is the indistinct small muscular area.

**Rhipidomella hybrida** (Sowerby) (Fig. 98). Orthis hybrida Sowerby (Hall. 1852. *Pal. N. Y.* 2:253, pl. 52)

Fig. 98 Rhipidomella hybrida

*Distinguishing characters.* Wider than long; nearly equal valves; pedicle valve with broad, undefined depression down the center; brachial valve uniformly convex, sometimes slightly depressed near front; beaks nearly equally elevated and scarcely incurved; short hinge area; fine bifurcating striae.

Found in the upper part of the lower Rochester shales and in the Bryozoa bed as well as rarely in the upper shales. Niagara sections. Also at Lockport and elsewhere (Hall).

**Rhipidomella circulus** Hall (Fig. 99). Orthis circulus Hall (1852. *Pal. N. Y.* 2:56, pl. 20)

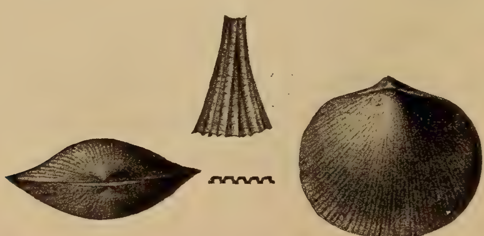


Fig. 99 Rhipidomella circulus with enlargement of surface

*Distinguishing characters.* Nearly circular and equivalve; finely striated surface; dichotomous striae running upward and outward on the hinge line; narrow short hinge area; slightly sinuous front.

Found in the lower Clinton limestone (?). Also east of Lockport (Hall).

Genus SCENIDIUM Hall

[Ety.: σκηνίδιον, little tent]

(1860. *N. Y. state cab. nat. hist. 13th rep't*, p. 70; 1892. *Pal. N. Y.* v. 8, pt 1, p. 241)

Shells subpyramidal, somewhat semicircular; with or without median sinus or elevation; pedicle valve elevated, subpyramidal; beak straight or slightly arched; cardinal area large, triangular, divided by a narrow fissure, sometimes closed at the summit by a concave plate. Brachial valve depressed convex to concave; cardinal line usually equal to width of shell; cardinal process simple or divided, and extending as a median septum through the length of the shell. Spondylium in the pedicle valve.

**Scenidium pyramidale** Hall (Fig. 100). Orthis pyramidale Hall (1852. *Pal. N. Y.* 2:251, pl. 52, fig. 2a-z)

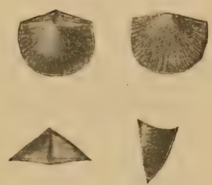


Fig. 100 Scenidium pyramidale enlarged

*Distinguishing characters.* Minute, subpyramidal; flat semicircular brachial valve, centrally depressed; extremely elevated pedicle valve with large triangular area; strong radiating striae, sometimes dichotomous; lamellose concentric striae.

Found in the Rochester shale at Lockport (Hall) and may also occur at Niagara.

Genus ANASTROPHIA Hall

[Ety.: ἀνά, back; στροφή, a turning]

(1867. *N. Y. state cab. nat. hist. 20th an. rep't*, p. 163; 1893. *Pal. N. Y.* v. 8, pt 2, p. 224)

Pentameroid shells with a spoon-shaped cavity (spondylium) under the beak of the pedicle valve and with a moderate cardinal line but no hinge area; surface with numerous sharp plications extending to the beak.

**Anastrophia interplicata** (Hall) (Fig. 101). Atrypa interplicata Hall (1852. *Pal. N. Y.* 2:275, pl. 57)

Fig. 101 Anastrophia interplicata

*Distinguishing characters.* Extremely convex; brachial valve the deepest; moderate sinus and fold; from two to three plications in the former and three to four on the latter; lateral plications increase by implantation.

Found in the Clinton lenses, and in the lower and middle Rochester shale at Niagara. Also in the shale at Lockport (Hall).

**Anastrophia brevirostris** Hall (Fig. 102) Atrypa brevirostris Hall (1852. *Pal. N. Y.* 2:278, pl. 58)

Fig. 102 Anastrophia brevirostris

*Distinguishing characters.* Wider than high; strongly convex; brachial valve deepest; short nearly equal beaks; sharp bifurcating or interpolated plications, from five to six in the sinus and fold, which are broad and ill defined.

Found in the lower Rochester shale at Niagara (?). Also in the shale at Lockport (Hall).

Genus PENTAMERUS Sowerby

[Ety.: πέντε, five; μέρος, part]

(1813. Sowerby. *Mineral conchology,* 1:76; Hall & Clarke. 1893. *Pal. N. Y.* v. 8, pt 2, p. 236)

Shell strongly inequivalve, biconvex with highly arched pedicle valve; surface smooth, or with a few broad and obscure radiating undulations. Under the beak of the pedicle valve is a deep and narrow *spondylium,* or plate with an excavated spoon-shaped cavity, supported by a high vertical septum of variable length; brachial valve with a pair of septa, the interior of the shell being thus divided into five compartments.

**Pentamerus oblongus** Sowerby (Fig. 103) (Hall. 1852. *Pal. N. Y.* 2:79, pl. 25)

*Distinguishing characters.* Very large and oblong, varying in outline with age; wider in anterior part; valves strongly convex at beaks; beak of pedicle valve overarching; subtrilobate division of

valves in some specimens; surface marked only by concentric lines of growth, which are strongest in old shells.

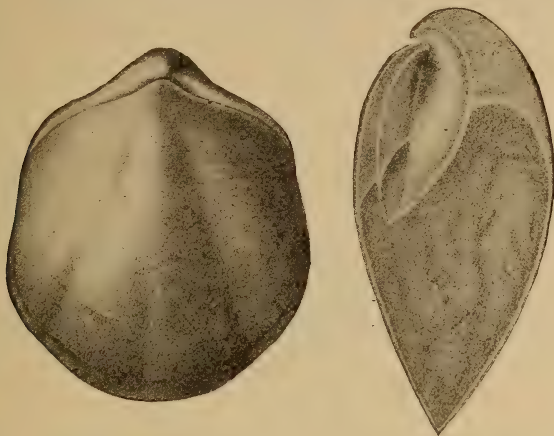


Fig. 103 Pentamerus oblongus

Found in the upper crystalline Clinton limestone at Niagara (1 specimen). The species is characteristic of the lower Clinton limestone, east of Lockport.

Genus BARRANDELLA Hall & Clarke

[Ety.: proper name]

(Hall & Clarke. 1894. *Pal. N. Y.* v. 8, pt 2, p. 241, 243)

Small pentameroid shells, of a galeate form or helmet-shaped contour, with a smooth, or rarely plicated surface. A spondylium is present, but is not supported by a septum.

**Barrandella fornicata** (Hall) (Fig. 104). Pentamerus fornicatus Hall (*Pal. N. Y.* 2:81, pl. 24)

Fig. 104 Barrandella fornicata

*Distinguishing characters.* Helmet-shaped contour, very convex pedicle valve, with overarching beak; surface obscurely plicate longitudinally.

Found in the upper crystalline Clinton limestone at Niagara. Also in the same limestone at Lockport (Hall).

## Genus RHYNCHOTRETA Hall

[Ety.: ῥύγχος, beak; τρητά, with a hole]

(1879. *N. Y. state mus. nat. hist. 28th an. rep't*, p. 166; 1893. *Pal. N. Y.* v. 8, pt 2, p. 185)

Shell triangular; surface with angular plications. Beak of pedicle valve straight, produced beyond that of the opposite valve, extremity perforate, the foramen with an elevated margin. Two longitudinally striated deltidial plates fill the delthyrium. Teeth slender, curving, proceeding from a broad curving hinge plate in the pedicle valve. Brachidium a slightly modified loop.

**Rhynchotreta cuneata** var. **americana** Hall (Fig. 105). Atrypa cuneata Hall (1852. *Pal. N. Y.* 2:276, pl. 57, fig. 4a-r)

Fig. 105 Rhynchotreta cuneata var. americana

*Distinguishing characters.* Triangular and cuneiform outline; longer than wide; elongate angular beak of pedicle valve with compressed, flat or concave sides; wide, deep sinus in adult, extending two thirds to the beak; profound frontal emargination; strong angular plications, three in sinus, four on fold, the two central ones most prominent; numerous regular, fine thread-like concentric striae; minutely papillose surface.

Found in the Clinton lenses and the lower Rochester shale and particularly in the Bryozoa beds, where it is abundant; rarely above this. Niagara sections. Also at Lockport and elsewhere (Hall).

## Genus CAMAROTOECHIA Hall & Clarke

[Ety.: καμάρα, arched chamber; τοῖχος, partition]

(1893. *Pal. N. Y.* v. 8, pt 2, p. 189)

Shell rhynchonelloid, trihedral in contour, with shallow pedicle and convex brachial valve; no hinge area; beak of pedicle valve projecting and incurved. Surface radially plicate, sinus and fold in pedicle and brachial valves respectively. Distinctive internal characters (separating this genus from other " Rhynchonellas ") are: a

median septum in the brachial valve, which divides posteriorly, so far as to form an elongate cavity, which does not extend to the bottom of the valve. No cardinal process. In the pedicle valve slender vertical lamellae support the teeth.

**Camarotoechia obtusiplicata** Hall (Fig. 106). Atrypa obtusiplicata Hall (1852. *Pal. N. Y.* 2:279, pl. 58, fig. 2a-h)

*Distinguishing characters.* Gibbous, subspheroidal form; strongly convex brachial, and flatter pedicle valve; deep sinus of pedicle

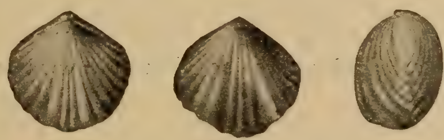


Fig. 106 Camarotoechia obtusiplicata

valve with three plications (rarely four); depressed incurved beak of pedicle valve; simple, obtusely rounded or flattened plications; faint concentric striae; strongly emarginate front.

Found in the lower part of the lower Rochester shales at Niagara. Also in the shales and limestones at Lockport (Hall).

**Camarotoechia (?) neglecta** Hall (Fig. 107). Atrypa neglecta Hall (1852. *Pal. N. Y.* 2:70, 274, pl. 23 and 57)

*Distinguishing characters.* Convex valves, brachial valve deepest, sides sloping abruptly to the beak; strongly defined sinus and fold, in adult individual, the former with three, the latter with four plications; profound frontal emargination; plications rounded.

Fig. 107 Camarotoechia (?) neglecta

Found in the lower Clinton limestone in the Clinton lenses and in the upper part of the lower and the middle Rochester shales at Niagara. Also more rarely in the upper shales. Found also at Lockport and elsewhere (Hall).

**Camarotoechia acinus** Hall (Fig. 108). Rhynchonella acinus Hall (*N. Y. state mus. nat. hist. 28th an. rep't,* p. 163, pl. 26)

*Distinguishing characters.* Small size; longitudinally ovate form, narrowing toward beak, truncate in front; subequally convex valves;

a single plication in sinus of pedicle valve and two on fold of brachial valve; few plications on either side of fold or sinus.

Fig 108 Camarotoechia acinus. A specimen in which the fold and sinus are not developed. Enlarged x 4

Found in the crystalline upper Clinton limestone at Niagara. The species was originally described from the western Niagara.

Genus RHYNCHONELLA Fischer de Waldheim

[Ety.: ῥύγχος, beak]

(1809. *Notice des fos. gouv. Moscow.* p. 35; Hall & Clarke. 1893. *Pal. N. Y.* v. 8, pt 2, p. 177, 178)

Subpyramidal plicated shells with a prominent anterior linguiform extension. Dental lamellae and a dorsal median septum occur, but no cardinal process; crura are present, but other arm supports are wanting.

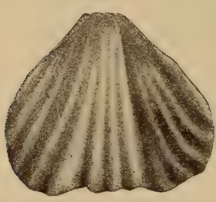


Fig. 109 Rhynchonella robusta

**Rhynchonella robusta** Hall (Fig. 109). Atrypa robusta Hall (1852. *Pal. N. Y.* 2:71, pl. 23)

*Distinguishing characters.* Large size; robust character; brachial valve most convex; broad, ill defined fold and sinus; coarse rounded plications.

Found in the uppermost beds of the Clinton series at Niagara. Also east of Lockport (Hall).

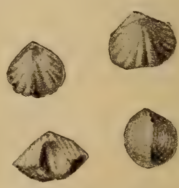


Fig. 110 Rhynchonella (?) bidens

**Rhynchonella (?) bidens** Hall (Fig. 110). Atrypa bidens Hall (1852. *Pal. N. Y.* 2:69, pl. 23)

*Distinguishing characters.* Much smaller than preceding; strong convexity of valves; deep sinus with one plication; fold consisting of two rounded plications; rather broad, rounded lateral plicae; strongly emarginate front.

Found in the lower Clinton beds at Lockport (Hall). Probably also at Niagara.

**Rhynchonella (?) bidentata** (Hisinger) (Fig. 111). Atrypa bidentata Hall (1852. *Pal. N. Y.* 2:276, pl. 57)

Fig. 111 Rhynchonella (?) bidentata with surface enlarged

*Distinguishing characters.* Triangular form; acute, extended beak of pedicle valve; stronger convexity of brachial valve; less convex and more triangularly acute than preceding; very slight frontal emargination; shallow sinus with one plication, and corresponding fold with two.

Found in the Rochester shale at Lockport and elsewhere (Hall). Probably also at Niagara.

Genus ATRYPA Dalman

[Ety.: α, without; τρῦπα, foramen (erroneous)]

(1828. *Kongl. Vetenskaps Akad. Handlingar*, p. 127; 1894. *Pal. N. Y.* v. 8, pt 2, p. 163)

Shell varying in outline from nearly circular to longitudinally suboval; valves very unequal, brachial valve being strongly convex or gibbous, while the pedicle valve is gently convex or almost flat or sometimes slightly concave from the strongly marked sinus; beak of the pedicle valve small and incurved over that of the brachial. Large widely separated and doubly grooved teeth are present, unsupported by lamellae. Strong muscular impressions. Spirals of the brachidium with their bases parallel to the inner surface of the pedicle valve, and the apexes directed toward the deepest point of the opposite valve. Surface radially plicate.

**Atrypa reticularis** (Linnaeus) (Fig. 112) (1852. *Pal. N. Y.* 2:272, pl. 23, p. 270, pl. 55)

Fig. 112 Atrypa reticularis

*Distinguishing characters.* Convex brachial and flat pedicle valves; small deeply incurved beaks; radiating and concentric striae forming reticulated surface.

Found in all the beds from the upper Clinton limestones to the Bryozoa beds. Most abundant in the Clinton.

In the light colored crystalline upper Clinton limestone this species is very abundant, but also very variable. Strong robust and very rotund specimens occur, with brachial valve excessively bulging, and with narrow simple rounded striae, increasing by implantation, and cancelated by concentric striae of moderate strength, and stronger undulations on the mature portions. Other specimens, less rotund and with bifurcating striae occur. When bifurcation of striae occurs, this is usually found on the pedicle valve, those of the brachial valve increasing only by intercalation. The pedicle valve usually has a sinus near the front, and the striae and concentric lines increase in strength, approaching the characters of the next species. In the Clinton lenses this character becomes still more pronounced, the shells at the same time decreasing in size and rotundity. In the Rochester shales the species is generally much less abundant, A. nodostriata being the prominent form. A. reticularis is represented by small and generally flattened specimens, in which the radiating striae are usually fine, and the concentric striae lamellose, specially in the adult portions. Increase of striae occurs by both intercalation and bifurcation, the former on the brachial, the latter on the pedicle valve. In some specimens the bifurcation occurs close to the beak.


Fig. 113 Atrypa nodostriata, with striae enlarged

**Atrypa nodostriata** Hall (Fig. 113) (1852. *Pal. N. Y.* 2:272, pl. 56)

*Distinguishing characters.* Subequal valves, nearly equally convex in young, pedicle valve more convex with age; small slightly elevated beak of pedicle valve; mesial sinus in adult shells, broad and undefined; strong rounded bifurcating plications; lamellose growth lines which give nodulose appearance to surface.

Found in the Clinton lenses, and the lower and middle Rochester shale at Niagara. Specially abundant in the Bryozoa beds. Also found at Lockport and elsewhere (Hall).

**Atrypa rugosa** Hall (Fig. 114) (1852. *Pal. N. Y.* 2:271, pl. 56)

*Distinguishing characters.* Generally smaller than preceding; equally convex valves in adult, unequal in young, the brachial valve

being almost flat. Strong sinus and fold in adult, with minor plications on each; strong concentric rugose lamellae; plications less rounded than preceding.

Found in the Clinton and Rochester beds at Niagara, generally associated with the preceding but much less common. Also at Lockport, etc. (Hall).

Fig. 114 Atrypa rugosa with striae enlarged

Genus CYRTINA Davidson

[Ety.: κυρτία, a wicker shield]

(1858. *British Carbon. Brachiopoda.* Monograph, p. 66; 1893. *Pal. N. Y.* v. 8, pt 2, p. 43)

Shells S p i r i f e r -like; usually small; valves very unequal; pedicle valve elevated, with a high cardinal area, the delthyrium of which is covered by an elongate, convex pseudodeltidium, which is perforated below the apex; surface plicate. Dental lamellae strong, converging rapidly, and meeting a median septum. Cardinal process a double apophysis. Brachidium an extroverted spire.

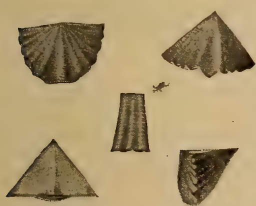


Fig. 115 Cyrtina pyramidalis with striae enlarged

**Cyrtina pyramidalis** (Hall) (Fig. 115). S p i r i f e r p y r a m i d a l i s Hall (1852. *Pal. N. Y.* 2:266, pl. 54)

*Distinguishing characters.* Pyramidal form; vertical or slightly bent area; nearly flat brachial valve; extremely convex pedicle valve; subangular plications, about five on each side of mesial fold and sinus.

Found " near the top and just below the edge of the cliff on the Niagara river above Lewiston " (Hall).

Genus SPIRIFER Sowerby

[Ety.: *spira,* spire; *fero,* to bear]

(1815. *Mineral conchology,* 2:42; 1894. Hall & Clarke. *Pal. N. Y.* v. 8, pt 2, p. 1)

Shell variously shaped, commonly very much wider than long, radially plicated or striated, crossed by concentric growth lines, which in some forms are lamellose or even marked by spines.

Hinge line generally long and straight; pedicle valve usually with moderately high area, with an open delthyrium, the margins of which are prolonged into stout simple teeth, supported by dental lamellae. Area of the brachial valve the lower. A calcareous brachidium in the form of a double spire, whose apexes are directed toward the cardinal angles, nearly fills the cavity of the shell.

**Spirifer radiatus** Sowerby (Fig. 116) (Hall. 1852. *Pal. N. Y.* 2:66, pl. 22, p. 265, pl. 54)

*Distinguishing characters.* Moderately large size; pedicle valve with strongly incurved beak, moderate area, and broad shallow

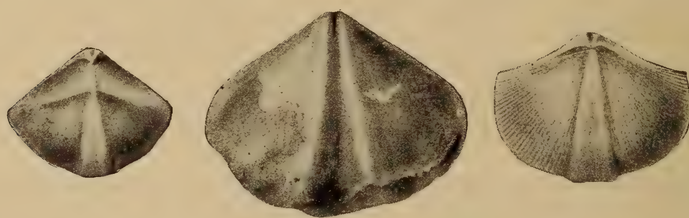


Fig. 116 Spirifer radiatus showing variation

mesial sinus; flattened median fold; fine uniform radiating striae covering all parts of the shell.

Found in the Clinton limestones and lenses and in the lower and middle Rochester shales at Niagara; sometimes abundant. Also at Lockport and elsewhere (Hall).

The shell varies greatly in form and proportions; sometimes the hinge area is much extended or the hinge extremities are rounded and the hinge line shorter than the shell below. Faint plications near the fold and sinus also occur in some specimens, connecting this species with the next.

**Spirifer niagarensis** Conrad (Fig. 117) (Hall. 1852. *Pal. N. Y.* 2:264, pl. 54)

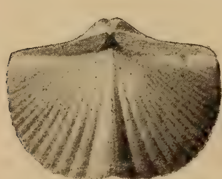


Fig. 117 Spirifer niagarensis

*Distinguishing characters.* Moderately large size; convex, with nearly equal valves; strongly incurved beak of pedicle valve; moderate area; numerous fine, rounded, depressed plications, which become obsolete toward the extremities, and sometimes appear quite flattened out on the surface; fine thread-like radiating striae covering plications and interspaces alike.

Found in the upper Clinton limestone and the Clinton lenses and abundantly throughout the lower and middle Rochester shale at Niagara. Also at Lockport and elsewhere (Hall).

**Spirifer crispus** (Hisinger) (Fig. 118) (Hall. 1852. *Pal. N. Y.* 2:262, pl. 54)

*Distinguishing characters.* Small size; very convex pedicle valve with incurved beak and high area, which does not extend to car-

Fig. 118 Spirifer crispus

dinal extremities; broad rounded plications, from six to eight on each valve, strongest near the fold and sinus; fine, elevated, thread-like concentric striae.

Found in the Clinton lenses and the lower and particularly the middle Rochester shale (Bryozoa beds) at Niagara. Also at Lockport and elsewhere (Hall).

**Spirifer crispus** var **corallinensis** Grabau. (*Geol. soc. Am. Bul.* 11:352; Hall. 1852. *Pal. N. Y.* 2:328, pl. 74, fig. 9a-h)

*Distinguishing characters.* Uniformly obsolescent plications, angular mesial sinus; otherwise like preceding.

Found in the Clinton lower limestone, the lenses, and the lower Rochester shale. Not abundant. This variety connects S. crispus with S. eriensis. It is characteristic of the Coralline limestone of eastern New York.

**Spirifer eriensis** Grabau (Fig. 119) (*Geol. soc. Am. Bul.* 2:366, pl. 21)

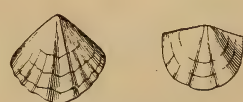


Fig. 119 Spirifer eriensis

*Distinguishing characters.* Ventricose pedicle valve, of subrhomboidal outline, high area, pronounced angular mesial sinus uniformly increasing in width forward, strong frontal emargination; sinus bounded by strong rounded prominent plications, with fainter

ones on either side; linear interspaces; sharply defined fold of brachial valve, with plications almost obsolete.

Found only in the Manlius limestone of North Buffalo and Williamsville. Not common.

**Spirifer (Delthyris) sulcatus** Hall (Fig. 120) (1852. *Pal. N. Y.* 2:261, pl. 54)

Fig. 120 Spirifer (Delthyris) sulcatus with striae enlarged

*Distinguishing characters.* Nearly equal valves; deep mesial sinus; four or more plications on either side, with wide interspaces; fine radiating striae crossing plications and interspaces; very coarse, lamellose, subequally spaced concentric growth lines which interrupt the radiating striae.

Found rarely in the Clinton lenses and the lower Rochester shale; more common in the Bryozoa beds at Niagara. Also at Lockport and elsewhere (Hall).

## Genus HOMOEOSPIRA Hall & Clarke

[Ety.: ὅμοιος, like; σπεῖρα, spire]

(1893. *Pal. N. Y.* v. 8, pt 2, p. 112)

Shell rostrate, radially plicate, and with a short curved hinge line; apex truncated by a circular pedicle opening. Spirals spiriferoid, with from six to nine volutions and a V-shaped jugum. A linear cardinal process separates the crural plates.

**Homoeospira apriniformis** Hall (Fig. 121). Atrypa aprinis Hall (1852. *Pal. N. Y.* 2:280, pl. 57)

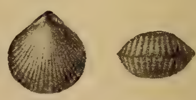


Fig. 121 Homoeospira apriniformis

*Distinguishing characters.* Small, roundish, oval, scarcely longer than wide; nearly equally convex valves; nonsinuate front, numerous simple rounded plications; fine concentric striae.

Found in the Rochester shale at Lockport (Hall). Probably also at Niagara.

Genus TREMATOSPIRA Hall

[Ety.: τρῆμα, foramen; σπεῖρα, spire]

(1859. *N. Y. state mus. nat. hist. 12th an. rep't*, p. 27; 1893. *Pal. N. Y.* v. 8, pt 2, p. 124)

Shells transverse, with subequally convex valves; surface radially plicate; hinge line straight, cardinal extremities abruptly rounded; anterior margin sinuate. Pedicle valve with a median sinus and an incurved beak, truncated by a circular foramen. Delthyrium covered by two short incurved plates, which are usually closely ankylosed, and appear continuous, with a narrow, flattened area on either side; lower half of the delthyrium open, for the reception of the beak of the brachial valve. Teeth prominent, arising from the bottom of the valve; above the hinge line they curve backward and toward each other, thus making a very firm articulation. Muscular area well defined. Brachial valve with median fold, and minute beak. Hinge plate greatly elevated, with a small chilidium resting against it; upper face of plate deeply divided by median longitudinal groove, and more faintly by transverse groove. Dental sockets small and deep, crura broad, thin and comparatively short. Brachidium of two spiral cones set base to base, as in Spirifer.

**Trematospira camura** Hall (Fig. 122). Atrypa camura Hall (1852. *Pal. N. Y.* 2:273, pl. 56)

Fig. 122 Trematospira camura

*Distinguishing characters.* Small; subrhomboidal to transversely elongate; nearly equally convex valves. Small, acute, projecting and slightly incurved beak of pedicle valve, showing in young shells the ankylosed deltidial plates; strong, distant, simple subangular plications, one or two fine ones in the center; fine, thread-like concentric striae and coarse lamellae.

Found in the Bryozoa beds of the Rochester shale at Niagara, rather common. Also at Lockport and elsewhere (Hall).

Genus WHITFIELDELLA Hall & Clarke

[Ety.: proper name]

(1893. *Pal. N. Y.* v. 8, pt 2, p. 58)

Shells usually of small size; valves subequally convex, ovate or elongate in outline; beak of pedicle valve not high or greatly in-

curved, usually exposing the circular apical foramen, beneath which the deltidial plates are frequently retained. Cardinal slopes of both valves broad and not distinctly defined; anterior margin subtruncate and gently sinuate. Hinge plate in brachial valve concave, divided by a deep central concavity, which is supported by a medium septum. Brachidium consisting of two spiral cones arranged base to base, connected by a V-shaped jugum.

**Whitfieldella nitida** Hall (Fig. 123). Atrypa nitida Hall (1852. *Pal. N. Y.* 2:268, pl. 55)

Fig. 123 Whitfieldella nitida

*Distinguishing characters.* Small size; strong convexity of valves, which are nearly equal, pointed incurved beak of pedicle valve; smooth surface except for concentric growth lines and strong wrinkles of growth; often slight sinus near the front of both valves, causing slight frontal emargination.

Found abundantly in the Clinton lenses and less commonly in the Rochester shale at Niagara.

This species varies from broadly to narrowly ovate; the thickness is frequently greater than the width and coarse thickenings and wrinkles show changes in growth. This may characterize senile individuals.

**Whitfieldella nitida** var. **oblata** Hall (Fig. 124). Atrypa nitida var. oblata Hall (1852. *Pal. N. Y.* 2:269, pl. 55)

*Distinguishing characters.* Broadly ovate form, angle between cardinal slopes often 90° or more; moderately convex valves, subtriangular in cross-section; uniformly rounded front; surface absolutely smooth, very deep muscular impressions.

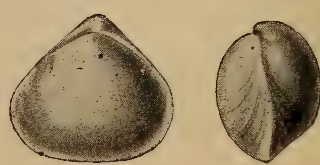


Fig. 124 Whitfieldella nitida var. oblata

Found in the Clinton lenses and the Rochester shale associated with the preceding and usually more abundant. Also at Lockport, etc. (Hall).

**Whitfieldella oblata** Hall (Fig. 125). Atrypa oblata Hall (1852. *Pal. N. Y.* 2:9, pl. 4)

*Distinguishing characters.* Oblate form, nearly as broad as high; broadest anteriorly; sloping abruptly to the beak; small, well

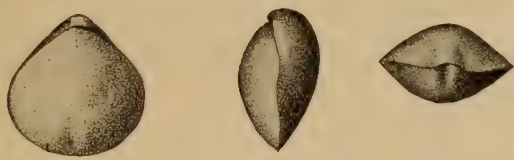


Fig. 125 Whitfieldella oblata

defined beak; nearly equally convex valves; central groove on pedicle valve and slight elevation on brachial valve; surface marked only by lines of growth.

Found in the upper Medina sandstone at Niagara. Also at Lockport (Hall).

**Whitfieldella intermedia** Hall (Fig. 126). Atrypa intermedia Hall (1852. *Pal. N. Y.* 2:77, pl. 24)

*Distinguishing characters.* Obovate; rapidly expanding to front, which is abruptly rounded; length and width nearly equal; convex near beak, flatter toward front; slight frontal sinuosity; faint growth lines.

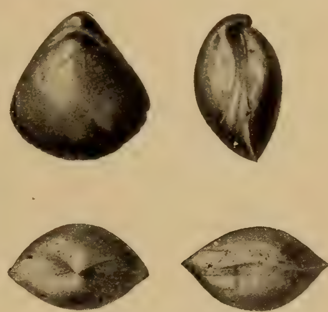


Fig. 126 Whitfieldella intermedia

Found in the Clinton lenses and lowest Clinton shales at Niagara. Also in the upper Clinton limestone at Lockport (Hall).

**Whitfieldella cylindrica** Hall (Fig. 127). Atrypa cylindrica Hall (1852. *Pal. N. Y.* 2:76, pl. 24)

Fig 127 Whitfieldella cylindrica

*Distinguishing characters.* Elongate cylindric; strongly convex; nearly as wide as thick; strongly overarching beak of pedicle valve;

faint mesial depression in pedicle valve; slight frontal sinuosity; fine radiating striae near the front.

Found in the upper Clinton limestone at Lockport (Hall). Probably also at Niagara.

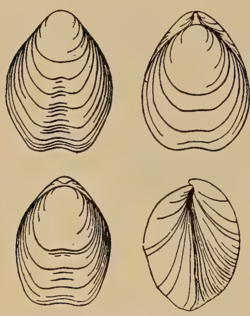


Fig. 128 Whitfieldella sulcata x 1½

**Whitfieldella sulcata** (Vanuxem) (Fig. 128) (Grabau. *Geol. soc. Am. Bul.* 11:367, pl. 22)

*Distinguishing characters.* Ventricose, elongate; well marked sinus in both valves; lines of growth and prominent wrinkles and changes in direction of growth.

Found in the Manlius limestone of North Buffalo, etc.

**Whitfieldella rotundata** (Whitfield) (Fig. 129) (Grabau. *Geol. soc. Am. Bul.* 11:368, pl. 22)

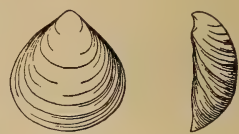


Fig. 129 Whitfieldella rotundata x 1½

*Distinguishing characters.* Small, subcircular; moderately convex; beak curved at right angles to plane of contact of valves.

Found in the Manlius limestone of Erie county (N. Y.)

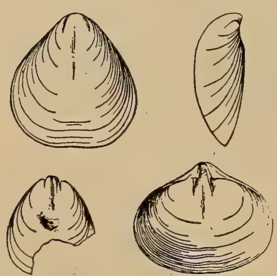


Fig. 130 Whitfieldella laevis x 1½

**Whitfieldella laevis** (Whitfield) (Fig. 130) (Grabau. *Geol. soc. Am. Bul.* 11:369, pl. 22)

*Distinguishing characters.* Small; broadly ovoid; moderately gibbous, greatest gibbosity in posterior third; faint mesial depression.

Found in the Manlius limestone of Erie county (N. Y.)

Genus HYATTELLA Hall & Clarke

[Ety.: proper name]

(1893. *Pal. N. Y.* v. 8, pt 2, p. 61)

Shell similar to Whitfieldella, but compactly subpentahedral, and without the median septum in the brachial valve.

**Hyattella congesta** (Conrad) (Fig. 131 and 131a). Atrypa congesta Hall (1852. *Pal. N. Y.* 2:67, pl. 23); Atrypa quadricostata Hall (*Pal. N. Y.* 2:68, pl. 23)

*Distinguishing characters.* Subcircular; gibbous; strongly convex pedicle valve with deep median furrow, deepening and widening forward; frontal linguiform elevation, obtuse carinated fold in sinus; strong fold on brachial valve, with a lateral fold on each side more or less prominent.

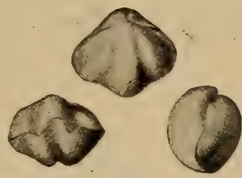


Fig. 131 Hyattella congesta

Fig. 131a Hyattella congesta

Found in the lower Clinton limestone at Niagara. Also at Lockport (Hall).

Genus ANOPLOTHECA Sandberger

[Ety.: ἄνοπλος, unarmed; θήκη, sheath]

(1853. *Sitzb. d. K. K. Akad. d. Wissens. math. naturw. Classe,* 16, p. 5, 18, 102; 1894. Hall & Clarke. *Pal. N. Y.* v. 8, pt 2, p. 129)

Concavo-convex, small shells with few plications crossed by fine often imbricating growth lines. Brachial valve with a high median septum. Brachidium a pair of spiral cones, as in Whitfieldella.

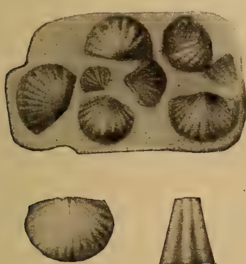


Fig. 132 Anoplotheca hemispherica with striae enlarged

**Anoplotheca hemispherica** (Sowerby) (Fig. 132). Atrypa hemispherica Hall (1852. *Pal. N. Y.* 2:74, pl. 23)

*Distinguishing characters.* Hemispheric to semiorbicular form; nearly flat brachial valve, convex pedicle valve; extended, nearly straight hinge line; eight to 12 rounded to subangular, simple plications; strong, undulating concentric striae.

Found poorly preserved in the Clinton shale at Niagara.

**Anoplotheca plicatula** (Hall) (Fig. 133). Atrypa plicatula Hall (1852. *Pal. N. Y.* 2:74, pl. 23)

*Distinguishing characters.* Slightly wider than long or sub-

rotund; cardinal slopes meeting in obtuse angle; young shell carinate toward the beak in the pedicle valve; brachial valve gently convex; median fold beginning as a depression at the beak, and becoming elevated near the front; two plications in sinus, three on fold; sharp rounded plications; strong frontal sinuosity; very fine concentric striae.

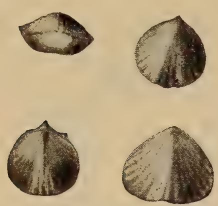


Fig. 133 Anoplotheca plicatula

Found in great abundance in the lower Clinton limestone at Niagara. Also east of Lockport (Hall).

## Class PELECYPODA Goldfuss

### (Lamellibranchiata Blainville)

The Pelecypoda, or Lamellibranchiata, are marine or fresh-water mollusks, with a bivalve shell. The valves are complementary, and in the majority of species are of nearly similar outline and size. In each valve may be distinguished an initial point, or beak, around which the concentric *lines of growth* mark the successive additions of shelly matter.

The orientation of most shells is effected by holding them with the *hinge line* uppermost and the beaks pointing away from the observer. Thus placed, the upper is the dorsal and the lower the ventral border. The end farthest away from the observer is the anterior end; that nearest, the posterior end. The valves are designated as the right and left valves respectively. The articulation of the valves is commonly effected by the interlocking of *teeth* which are borne on the hinge or cardinal margin of the valves. They vary greatly, but can usually be divided into the short, stout cardinal teeth, which are situated under or near the beak, and the ridge-like lateral teeth. The opening of the valves is brought about by an elastic ligament stretched across the hinge from valve to valve, behind the beak, which acts, on the principle of the C spring, whenever the tension of the *adductor muscles*, which close the valves, is relaxed. In many genera, an elastic, compressible cartilage, the

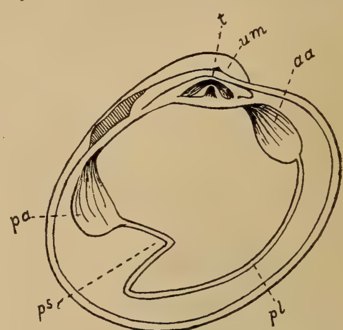



Fig. 134 Diagrammatic view of left valve of Cytherea; (aa) anterior adductor scars; (pa) posterior adductor scars; (pl) pallial line; (ps) pallial sinus; (t) teeth; (um) umbo; (l) ligament

*resilium* occurs, which is lodged in special grooves or pits. The scars marking the attachment of the adductor or closing muscle or muscles, vary greatly, and are frequently preserved in the fossil forms. When two are present, they are designated, respectively, the anterior and posterior adductor scars. The line of attachment of the fleshy mantle which builds the shells, i. e. the *pallial line,* is often visible. Near the posterior end it frequently makes a re-entrant curve—the *pallial sinus*—indicating that the animal had a retractile siphon. The various parts described are indicated in fig. 134.

The principal soft parts of the animal comprise: the *mantle*, consisting of two fleshy folds, one lining each valve, and building it; the *abdomen*, with the anteriorly placed *mouth*, and the antero-ventral *foot;* the *gills*, or *branchiae*, which consist of complicated lamellae hanging on either side of the abdomen in the mantle cavity; and the *siphons*—present only in certain forms—posteriorly placed, often capable of great extension, and serving, the one for the entrance of the water and food particles, and the other for the exit of the water and waste products.

### Genus PTERINEA Goldfuss

[Ety.: πτερόν, wing]

(1826. *Petrefacta Germaniae*, p. 133)

Shell inequivalve, inequilateral; posterior side winged, anterior end nasute or with a well defined ear. Ligament internal; ligamental area longitudinally striated. Cardinal teeth two or more; lateral teeth linear oblique. Posterior muscular impression large, situated on the post-umbonal slope; anterior muscular impression small, situated within the rostral cavity. Test ornamented with rays.

**Pterinea emacerata** (Conrad) (Fig. 135). Avicula emacerata Conrad (Hall. 1852. *Pal. N. Y.* 2:228, pl. 59)

*Distinguishing characters.* Moderately oblique; large and posteriorly concave wing often extending beyond the shell below; small anterior ear; flat, smooth right valve with striated wing; convex left valve, with strong radii, interrupted by fainter concentric striae.

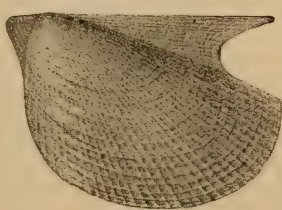


Fig. 135 Pterinea emacerata

Found perhaps in the Clinton shale, rarely in the lower and middle Rochester shale and abundantly in the upper shale. Niagara sections. Also at Lockport and elsewhere (Hall).

Genus LIOPTERIA Hall

[Ety.: λεῖος, smooth; πτερόν, wing]

(1883. *Pal. N. Y.* v. 5, pt 1, p. 4)

Shell aviculoid, oblique, subrhomboidal; anterior end not auriculate; wing large, extremity produced. Hinge narrow, furnished with a slender lateral tooth just posterior to the beak and nearly parallel to the hinge line. Ligament external; ligamental area narrow, extending the entire length of the hinge, marked by fine, sharp, longitudinal striae. Test with concentric striae but without rays.

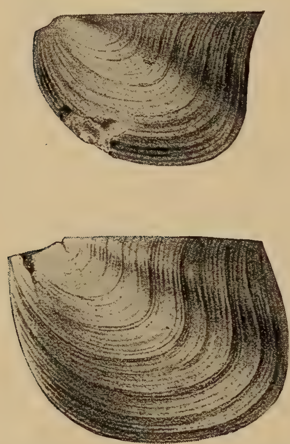


Fig. 136 Liopteria (?) subplana

**Liopteria (?) subplana** (Hall) (Fig. 136). Avicula subplana Hall (1852. *Pal. N. Y.* 2:283, pl. 59)

*Distinguishing characters.* Depressed convex surface; similarity of right and left valves; ill defined wing and ear; concentric striae; absence of radii.

Found in the Rochester shale at Lockport associated with Pterinea emacerata, etc. (Hall). Probably also at Niagara. The generic reference is provisional.

Genus LYRIOPECTEN Hall

[Ety.: λύριον, small lyre; *pecten,* comb, i. e. the genus Pecten]

(1884. *Pal. N. Y.* v. 5, pt 1, p. 12)

Shell inequivalve, with a short hinge line and very small anterior ear. Cartilage in shallow furrows, parallel to the hinge margin. Surface ornamented with rays.

**Lyriopecten orbiculoides** (nom. nov.) cf. Avicula (?) orbiculata Hall (1852. *Pal. N. Y.* 2:284, pl. 59)

*Distinguishing characters.* Right (?) valve convex; left (?) valve flat; form suborbicular, hinge line short, straight; strong radiating striae cancelated by equally strong concentric striae, forming surface similar to Pterinea emacerata.

Found in a loose block of limestone, probably the lower Lockport limestone, at Niagara. One specimen.

The identification with Hall's species and the generic reference are provisional.

Genus MODIOLOPSIS Hall

[Ety.: M o d i o l u s, a genus of recent shells; ὄψις, appearance (similar to)]

(1847. *Pal. N. Y.* 1:157)

Shells equivalve; valves elongate oval, closed, with nearly terminal beaks and narrow hinge plate, and without teeth; adductor scars subequal; ligament deep-seated.

**Modiolopsis orthonota** (Conrad) (Fig. 137) (Hall. 1852. *Pal. N. Y.* 2:10, pl. 4 bis)

*Distinguishing characters.* Subelliptic or rhomboidal form; straight hinge line; obliquely truncated anterior and rounded posterior ends; ventral and dorsal margins nearly parallel; elevated, thin, sharp umbones, with a faint ridge extending to the posterior basal margin; surface with concentric growth lines only.

Fig. 137 Modiolopsis orthonota

Found in the upper Medina sandstones at Niagara. Also in the same beds at Lockport, usually as molds.

**Modiolopsis primigenia** (Conrad) (Fig. 138) (Hall. 1852. *Pal. N. Y.* 2:10, pl. 4 bis)

*Distinguishing characters.* Subrhomboidal form; rounded anterior and expanded alate posterior ends; straight hinge line, produced posteriorly; rounded ventral margin; fine radiating striae visible only in well preserved shells; strong concentric growth lines.

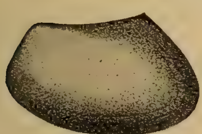


Fig. 138 Modiolopsis primigenia

Found usually as internal molds, in the upper Medina sandstones of the Niagara sections, and at Lockport and elsewhere.

**Modiolopsis** sp. (Compare M. s u b a l a t u s. *Pal. N. Y.* 2:84, pl. 27, fig. 5, 6; p. 285, pl. 59, fig. 7)

*Distinguishing characters.* A small left valve, strongly convex below the umbo; a strong cardinal ridge extends from beak to pos-

terior basal margin, and above this the surface of the posterior wing is slightly concave; beaks incurved, hardly raised above the hinge line; posterior end more sharply rounded than anterior; surface with concentric striae.

Found in the Clinton lenses on the Rome, Watertown and Ogdensburg railroad.

## Class GASTROPODA Cuvier

The gastropods, or snails, are mollusks with a distinct head, a muscular foot, and a mantle consisting of a single lobe. They are terrestrial, marine, or fresh-water animals, and are commonly protected by a conic or spirally coiled shell, which is secreted by the mantle. The apical part of the shell usually consists of a simple coiled embryonic shell, or *protoconch.* Succeeding this is the shell proper, which, when coiled comprises few or many *whorls,* the later overlapping the earlier ones to a greater or less extent. The *suture* at the junction of the overlapping whorls may be faintly or strongly impressed. The whorls may coil closely, forming a compact central *columella;* or they may be loosely coiled, leaving a hollow columella, opening below in the *umbilicus.* The body whorl opens in the aperture, the rim or *peristome* of which consists of an *outer* and an *inner,* or *columellar lip.* The peristome is *complete* when both inner and outer lip are present, and *incomplete* when the place of the inner lip is taken by the preceding whorl. In a great many species the peristome is notched anteriorly, or produced into a straight, or more or less flexed canal. A posterior notch is also frequently found. The columellar lip and, in its absence, the columella, may be smooth or furnished with one or more plications. Similarly, the outer lip may be smooth on its inner side or furnished with plications or *lirae.* Among the external features of importance are the transverse *lines of* growth, which mark the successive increments; *varices* or rows of spines, parallel to the lines of growth, and marking periodic resting stages during the growth of the shell; and revolving longitudinal lines or ridges, which may be uniform or alternating, or may show a gradation in size. When transverse and longitudinal lines cross each other, a reticulated surface ornamentation is produced; and, when the shell is covered by an epidermis, or *periostracum,* hair-like spines not infrequently arise from the points of crossing. In Pleurotomaria and related gastropods, a siphonal notch occurs in the outer lip, and its progressive closure from behind leaves a marked revolving band, commonly visible only on the body whorl.

Many species, specially of marine gastropods, secrete a horny or calcareous *operculum,* which is attached to the foot, and closes the aperture of the shell when the animal is withdrawn. This is seldom preserved in a fossil state.

Genus PLATYCERAS Conrad

[Ety.: πλατύς, flat; κέρας, horn]

(1840. *An. rep't pal. N. Y.* p. 205)

Shell conic, irregular, with or without the apex inrolled; aperture expanded, often reflexed; peristome entire, often sinuous; surface variously striated, sometimes bearing spines.

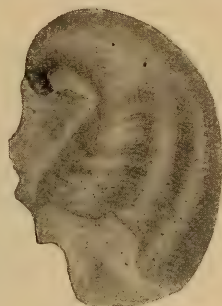


Fig. 139 Platyceras niagarense

**Platyceras niagarense** (Hall) (Fig. 139). Acroculia niagarensis Hall (1852. *Pal. N. Y.* 2:288, pl. 60)

*Distinguishing characters.* Involute apex, scarcely forming a volution; gradually expanding lower portion, with two or three longitudinal folds or undulations; transverse striae, which undulate across the folds and depressions.

Found rarely in the lower Rochester shale at Niagara. Also at Lockport (Hall).

**Platyceras angulatum** (Hall) (Fig. 140). Acroculia angulata Hall (1852. *Pal. N. Y.* 2:289, pl. 60)

Fig. 140 Platyceras angulatum

*Distinguishing characters.* Attenuated apex, forming one or two minute volutions; shell below extending in a broad curve, and expanding rapidly toward the aperture, which is much dilated; angulated surface, with a sharp carina on the upper and lower outer margins, and an obtuse carina in the middle; transverse section unequally pentagonal.

Found in the lower and middle Rochester shale at Niagara. Rare. Also at Lockport (Hall).

Genus DIAPHOROSTOMA Fischer

[Ety.: διάφορος, unlike; στόμα, mouth]

(1885. *Manual de Conchyliologie;* Platyostoma Conrad. 1842. *Acad. nat. sci. Jour.* 8:275)

Shell with a short depressed spire, a large dilated aperture and with the inner lip lying close against the body whorl.

**Diaphorostoma niagarense** Hall (Fig. 141) (1852. *Pal. N. Y.* 2:287, pl. 60)

*Distinguishing characters.* Globose contour; three to four volutions; large body whorl, inflated toward the dilated aperture; deeply depressed sutures; fine longitudinal and strong transverse striae. Not infrequently a sinuosity is indicated by the lines of growth.

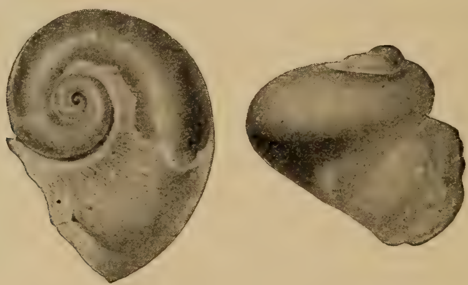


Fig. 141 Diaphorostoma niagarense

Found in the Clinton limestone lenses, and the lower and middle, and rarely the upper Rochester shale at Niagara. Also at Lockport and elsewhere (Hall).

Genus PLEUROTOMARIA De France

[Ety.: πλευρά, side; τομή, a cut]

(1824. *Tableau d. corps organises fossiles*, p. 114, and *Dict. sci. nat.* 41:381)

Shell T r o c h u s -shaped, more or less conic, with or without umbilicus; volutions angular, flattened, or rounded, their surfaces variously ornamented; aperture subquadrate to suborbicular, the inner lip thin. The outer lip bears a narrow, deep fissure or sinus, which is the unclosed continuation of a revolving band.

**Pleurotomaria littorea** Hall (Fig. 142) (1852. *Pal. N. Y.* 2:12, pl. 4 (bis))

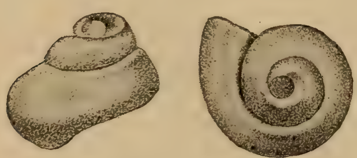


Fig. 142 Pleurotomaria littorea

*Distinguishing characters.* Medium size; subconical form; three to four somewhat obtusely angular volutions, which enlarge rapidly; small umbilicus.

Found in the upper Medina sandstone at Lockport (Hall). Fragments in the same rock at Niagara seem to be of this species.

**Pleurotomaria pervetusta** (Conrad) (Fig. 143) (1852. *Pal. N. Y.* 2:12, pl. 4 (bis))

*Distinguishing characters.* Small size; depressed conic spire, the volutions strongly embracing; whorls about four, gradually enlarging; large umbilicus extending to the apex.

Found in the upper Medina sandstones of the Niagara sections. Also at Lockport (Hall).

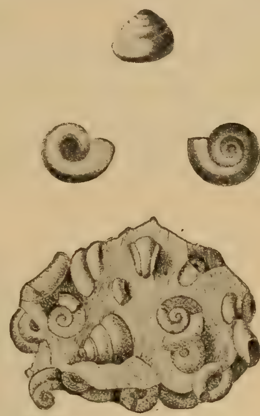


Fig. 143 Pleurotomaria pervetusta

Genus BUCANIA Hall

[Ety.: *bucina,* a trumpet]

(1847. *Pal. N. Y.* 1:32)

Shells coiled, a single plane, with the spire equally concave on either side and all the volutions visible; outer whorl ventricose; all whorls embracing to some extent, having an inner concavity; aperture rounded, oval, somewhat compressed on the inner side from contact with preceding whorl.

Fig. 144 Bucania trilobata

**Bucania trilobata** (Conrad) (Fig. 144) (Hall. 1852. *Pal. N. Y.* 2:13, pl. 4 (bis))

*Distinguishing characters.* Suborbicular form; three-lobed volutions, all of which are visible; last whorl greatly expanded; aperture wider than long.

Found at Medina and Lockport and fragments in the upper Medina of Niagara indicate its presence there.

## Class CONULARIDA

Paleozoic mollusks of doubtful systematic position, resembling some modern Pteropoda, but only distantly and ancestrally related to them. Shells conic or tubular, elongate, septate and variously ornamented.

Genus CONULARIA Miller

[Ety.: diminutive of *conus,* a cone]

(1821. Sowerby. *Mineral conchology,* 3:107)

Shell elongated, pyramidal, with the transverse section varying from quadrangular to octagonal; angles indented by longitudinal grooves. The surface is variously ornamented by transverse or

reticulated striae. Near the apex the shell is furnished with a transverse septum.

**Conularia niagarensis** Hall (Fig. 145) (1852. *Pal. N. Y.* 2:294, pl. 65)

*Distinguishing characters.* Broad, pyramidal, tapering abruptly; deep abrupt channels of the angles; shallow, scarcely defined depression of centers of faces; fine and closely arranged transverse striae, which extend from the angles obliquely to the center, and

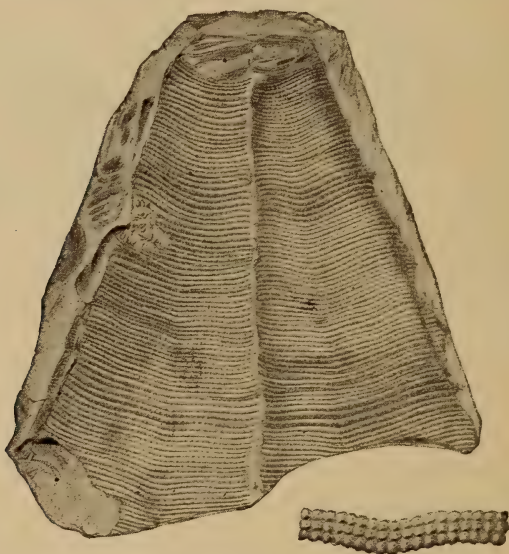


Fig. 145 Conularia niagarensis with several striae enlarged

bend more abruptly in crossing the central depression; granulate character of striae; intermediate spaces with longitudinal striae.

Found in the Rochester shale at Lockport (Hall). Probably occurs also at Niagara.

## Class CEPHALOPODA Cuvier

The cephalopods are the most highly developed mollusks, possessing a distinct, well defined head, a circle of eight or more arms surrounding the mouth and generally furnished with suckers or hooks, a funnel-like *hyponome*, or swimming organ, and a highly developed nervous system. The majority of modern genera are naked, or with only a rudimentary internal shell (squids, cuttlefish, etc.). Nautilus is the only modern genus with a typical external shell.

The shells of cephalopods are chambered, i. e. divided, by a series of transverse floors or *septa*, into *air chambers*. The last or *living*

*chamber* lodges the animal. The septa are pierced by a corresponding series of holes, the walls of which are often prolonged backward or forward into *siphonal funnels*, the whole constituting the *siphuncle.*

In the Nautiloidea, the sutures are, as a rule, simple or but slightly lobed, and the siphuncle is commonly central or eccentric, but seldom marginal, with the funnels generally directed backward. The embryonic shell, or protoconch, is rarely retained.

Fig. 146 Orthoceras multiseptum

The shells of cephalopods are either straight (more or less conic) or variously curved and coiled to close involution.

## NAUTILOIDEA

### Genus ORTHOCERAS Breyn

[Ety.: ὀρθός, straight; κέρας, horn]

(1732. *Dissertatio physica de polythalamiis*)

Shell a straight conic tube, with a large body chamber and numerous air chambers, separated by convex septa. Sutures simple, at right angles to the long axis of the shell; siphuncle central, subcentral, or eccentric, cylindric or sometimes widening in the chambers. Surface smooth or variously ornamented by transverse or longitudinal striae, or by annulations.

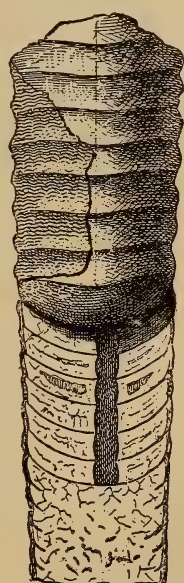


Fig. 147 Orthoceras annulatum. Terminal portion showing shell of living chamber and sectioned camerae (after Barrande)

**Orthoceras multiseptum** Hall (Fig. 146) (1852. *Pal. N. Y.* 2:14, pl. 4 (bis) )

*Distinguishing characters.* Cylindric, gradually tapering; septa distant one sixth to one seventh the diameter.

Found in the upper Medina sandstone at Lockport, etc. (Hall). Probably also at Niagara.

**Orthoceras annulatum** Sowerby (Fig. 147). Orthoceras undulatum Hall (1852. *Pal. N. Y.* 2:293, pl. 64, 65)

*Distinguishing characters.* Strong annulations; moderately strong longitudinal lines which node the annulations, fine transverse striae; elliptic cross-section; subcentral siphuncle.

Found in the Clinton limestone lenses in the Rome, Watertown and Ogdensburg railroad cut above Lewiston. Also in the Roches-

ter shale and Lockport limestone at Lockport (Hall), and probably also at Niagara.

**Orthoceras medullare** Hall (1860. *Geol. sur. Wis. Rep't prog.* p. 4)

*Distinguishing characters.* Cylindric, gradually tapering form; septa distant nearly half the diameter; large siphuncle, slightly expanded between septa; strong sharp subequal longitudinal striae, with often alternating finer striae; smooth cast.

Found in the Clinton limestone lenses in the Rome, Watertown and Ogdensburg railroad section above Lewiston. Rare. The species is normally a western one.


Fig. 148 Cyrtoceras subcancellatum

Genus CYRTOCERAS Goldfuss

[Ety.: κυρτός, curved; κέρας, horn]

(1837. *De la Beche, Handb. d. Geogn. bearb. von v. Dechen.* p. 536)

Shell conic and gently curved, with a depressed elliptic to trigonal cross-section, the aperture in old shells contracted to a T-shaped opening; siphuncle large, eccentric.

**Cyrtoceras subcancellatum** Hall (Fig. 148). Cyrtoceras (?) cancellatum Hall (1852. *Pal. N. Y.* 2:290, pl. 61)

*Distinguishing characters.* Arcuate; transversely oval section; transversely striated surface, and faint longitudinal striae; siphuncle submarginal.

Found in the "limestone below the cliff at Niagara Falls" (Hall).

Genus GOMPHOCERAS Sowerby

[Ety.: γνόμφος, a pin, bolt, or club; κέρας, a horn]

(1839. Murchison. *Silurian system,* p. 620)

Shell straight or curved, pear-shaped, greatest diameter in front of the middle; cross-section circular; mouth contracted, opening by a T-shaped aperture; siphuncle central or eccentric, subcylindric or expanding between the septa (moniliform).

**Gomphoceras ? sp.** (Hall. 1852. *Pal. N. Y.* 2:290, pl. 61)

*Distinguishing characters.* Subfusiform aperture narrowed, gradually tapering to the extremity; surface striated transversely.

This fossil has the general form and appearance of Gomphoceras, though I am unable to discover any marks of septa. The greatest expansion appears to be at about one third of the distance from the aperture to the apex.

Found "in a fragment of limestone below the cliff at Niagara Falls" (Hall).

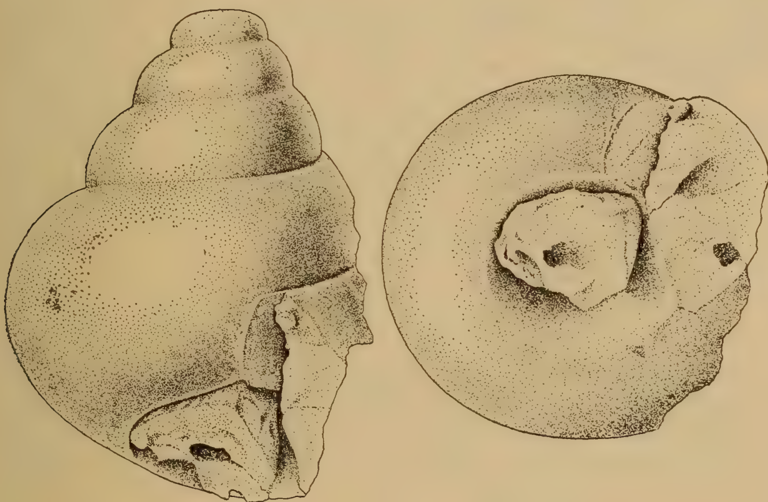


**Fig. 149 Trochoceras gebhardi, two thirds natural size**

Genus TROCHOCERAS Hall

[Ety.: τροχός, a wheel; κέρας, a horn (named from its trochus or top-like shape)]

(1852. *Pal. N. Y.* 2:335)

Shells turbinate or trochiform; spire elevated as in Gastropoda, more or less ventricose and umbilicated; aperture rounded or round oval; volutions above the outer one with septa; siphuncle submarginal or dorsal.

**Trochoceras gebhardi** Hall (Fig. 149) (1852. *Pal. N. Y.* 2:335, pl. 77, 77A; Grabau. *Geol. soc. Am. Bul.* 11:371, pl. 21)

*Distinguishing characters.* Deep and wide umbilicus with angular margins; cross-section of body whorl irregularly subhemispheric;

apical angle of spire about 60°; fine crowded surface striae. In the specimens so far obtained from the Manlius limestone, no septa have been preserved.

Found in the Manlius limestone of North Buffalo (Vogt & Piper, fig. 149) and Williamsville. The species was originally described from the Coralline limestone (Niagara) of Schoharie county (N. Y.)

## Class CRUSTACEA Lamarck

### Order OSTRACODA Latr.

The ostracods are small crustacea, with a bivalve, calcareous or horny shell covering the entire body. The valves are joined dorsally by a membrane, and open along the ventral side. The body is indistinctly segmented, and bears seven pairs of appendages, two pairs of which represent the trunk limbs. The shell corresponds to the carapace of the higher crustaceans. These organisms are minute and will ordinarily be overlooked unless search is made for them with a lens on the surfaces of the shale laminae. They are specially abundant in the finer grained shales.

#### Genus ISOCHILINA Jones

[Ety.: ἴσος, equal to; χεῖλος, lip]

(1858. *Can. organic remains,* Decade 3, p. 197)

Carapace with equal valves, whose margins meet uniformly and do not overlap; greatest convexity central, or toward the anterior end; anterior tubercle present.

**Isochilina cylindrica** (Hall). Cytherina cylindrica Hall (1852. *Pal. N. Y.* 2:14, pl. 4)

*Distinguishing characters.* Oval, elongate form; great convexity, " which, when both valves are joined, would give an almost cylindrical form to the shell ".

Found in the upper Medina sandstones at Medina (Hall), but probably also at Niagara and other places.

#### Genus LEPERDITIA Rouault

[Ety.: Leperdit, proper name]

(1851. *Soc. geol. France. Bul.* ser. 2, 8:377)

Carapace with unequal valves, the right valve the larger and overlapping the left valve, along the ventral and, to some extent, along the anterior and posterior ends; valves smooth, oblong and horny.

**Leperditia scalaris** Jones (Fig. 150) (Grabau. *Geol. soc. Am. Bul.* 11:371, pl. 22)

*Distinguishing characters.* Bean-shaped outline; straight hinge line with salient angles; uniformly curved basal margin; anterior and posterior marginal borders; ocular tubercle about a third the length of the shell from the anterior end; strong, elongated fold or "dorsal hump" below the hinge line, in the posterior half of the left valve.

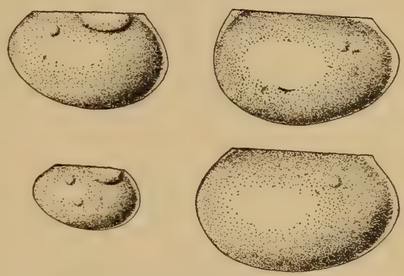


Fig. 150 Leperditia scalaris (enlarged)

Found in the Manlius limestone of North Buffalo and elsewhere in Erie county. It is a common species.

Genus BOLLIA Jones & Holl

[Ety.: Boll, proper name]

(1886. *An. and mag. nat. hist.*, ser. 5, 17:360)

Valves oblong, with rounded and nearly equal ends; hinge line straight, ventral margin curved; surface punctate and bearing a rudely horseshoe-shaped ridge, with a central depression within, and without a semilunar ridge on each side and parallel to the outer margins of the shell, which are slightly rimmed.

**Bollia symmetrica** (Hall) (Fig. 151). Beyrichia symmetrica Hall. (1852. *Pal. N. Y.* 2:317, pl. 67)

*Distinguishing characters.* Extremely small size; thin horseshoe ridge, dividing shell into three nearly equal parts; ridges and interspaces about equal; outer ridges not continued ventrally.

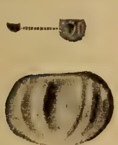


Fig. 151 Bollia symmetrica natural size and enlarged

Found in a fragment of weathered Rochester shale, on the talus along the Rome, Watertown and Ogdensburg railroad cut above Lewiston. Associated with the next. (One specimen found was larger than the normal, and the horseshoe curve rather thick ventrally, but not as thick as in B. lata of the Clinton group. This appears intermediate between the two species.) Also found at Lockport (Hall).

Genus AECHMINA Jones & Holl

[Ety.: ἀιχμή, point of a spear]

(*An. and mag. nat. hist.* ser. 4. 3:217)

Carapace with thick valves, straight at hinge line, rounded at the ends, and convex at the ventral border. Surface drawn out into a broad-based and sharp pointed hollow cone, which either involves the whole surface, or rises from the postero-dorsal or centro-dorsal region.

**Aechmina spinosa** (Hall) (Fig. 152). Cytherina spinosa Hall (1852. *Pal. N. Y.* 2:317, pl. 67)

Fig. 152 Aechmina spinosa much enlarged After Jones

*Distinguishing characters.* Strong oblique spine, thick and hollow at the base, either elongate or short; pointed upward, outward and forward, and sometimes slightly bent; valves thickened on the free border by a raised, rounded but irregular margin; area at base of spine hollow and smooth; raised margin sometimes punctate; spine often long and projecting beyond the upper margin of the valve.

Found in weathered Rochester shale on the talus of the Rome, Watertown and Ogdensburg railroad cut above Lewiston. The valves are often imbedded in the shale with the inner concave surfaces exposed. Also found at Lockport (Hall).

Order TRILOBITA Burmeister

The trilobites are extinct Crustacea, wholly confined to the Paleozoic seas. The body was covered with a carapace longitudinally divisible into three parts. The anterior portion comprises the head-shield, or *cephalon*, which is usually semicircular, with a straight posterior border. The central of the three cephalic lobes is the *glabella,* which is the most prominent part of the cephalon. It is of varying outline, and more or less divided by transverse furrows or pairs of furrows. The last furrow is the *occipital furrow,* and delimits the *occipital ring,* which is just anterior to the first segment of the thorax. On either side of the glabella is a pair of cheeks, divided by the *facial suture* into *fixed cheeks* (those next to the glabella) and *free cheeks* (the outermost portion). The latter are often prolonged into

*genal spines.* The compound eyes are situated on the free cheeks, and they are overshadowed by more or less prominent eyelids or *palpebral lobes,* which are lateral lobes from the fixed cheeks. The facial suture thus passes between the eyes and the palpebral lobes, and when, as is often the case, the free cheeks become separated after the death of the animal, only the palpebral lobes remain on the central portion of the cephalon. The border of the cephalon is often distinctly marked, and is spoken of as the *cephalic limb.* At the margin it is folded down and under, making the *doublure,* which, continued backward, often produces hollow or solid genal spines. Near the anterior lower portion of the doublure lies the lower lip, or *hypostoma,* which is usually found separate.

The *thorax* consists of a varying number of segments or rings, articulated with each other, and commonly permitting enrolment. Each consists of a central *annulus* and lateral *pleurae.*

The tail, or *pygidium,* consists of a single piece, comprising a central *axis* and lateral *lobes.* The axis and the lobes commonly show transverse furrows, corresponding to the divisions of the thorax, and they are often so strongly marked that a line of division between thorax and pygidium is difficult to determine.

Great advances have recently been made in our knowledge of the ventral side of trilobites. Probably all of them had jointed appendages, which included antennae, mouth parts and legs, comparable in a general way to those of modern Crustacea.

### Genus HOMALONOTUS Koenig

[Ety.: ὁμαλός, on the same level; νῶτος, back]

(1825. *Icones foss. sectiles,* p. 4)

Body usually large, depressed above, with abruptly sloping sides. The axial furrows are indistinct or obsolete. Cephalon depressed convex, wider than long, with rounded genal angles, and somewhat produced anterior margin; glabella almost rectangular, smooth, or with faint lateral furrows. Small eyes situated behind the middle, and converging facial sutures are characteristic. Thorax of 13 deeply grooved segments. Pygidium smaller than the cephalon, elongate triangular, rounded or produced posteriorly; axis with 10 to 14 annulations; lateral lobes smooth or with posteriorly sloping ribs.

**Homalonotus delphinocephalus** (Green) (Fig. 153) (Hall. 1852. *Pal. N. Y.* 2:309, pl. 68)

*Distinguishing characters.* Subtriangular cephalon; subquadrate glabella, widening a little posteriorly; small lateral eyes; acute anterior termination of cephalon; non-trilobate character of thorax, narrowing rapidly toward the posterior end; abruptly triangular pygid-

ium ending acutely, faintly trilobate, and strongly ringed both on the axial and lateral portions; granulose surface.

Fig. 153 Homalonotus delphinocephalus, ⅔ natural size

Found rarely in the lower Rochester shale at Niagara, but common in the upper shales. Also found at Lockport and elsewhere (Hall).

Genus ILLAENUS Dalman

[Ety.: *ἰλλαίνω*, to squint]

(1828. *Ueber die Palaeaden*, p. 51)

Cephalon and pygidium of about the same size, large and convex, smooth, semicircular in outline, with the trilobations faintly or not

at all marked in either. Glabella smooth, indistinct, eyes large, round, lateral cheeks small. Thorax usually consisting of 10 segments, with smooth pleurae.

**Illaenus ioxus** Hall (Fig. 154). Bumastis barriensis Hall (1852. *Pal. N. Y.* 2:302, pl. 66)

Fig. 154 Illaenus ioxus

*Distinguishing characters.* Elongate elliptic form; rounded, nearly equal cephalon and pygidium, with the trilobation scarcely marked; large eyes near the posterior lateral border of the cephalon; faint trilobation of thorax with very broad central lobe; granulose or punctate surface.

Found in the Clinton limestone lenses in great abundance, usually represented only by cephala and pygidia. These are often crowded together in great profusion to the exclusion of nearly every other fossil. Also found rarely in the lower and middle Rochester shale at Niagara. Also found at Lockport and elsewhere (Hall).

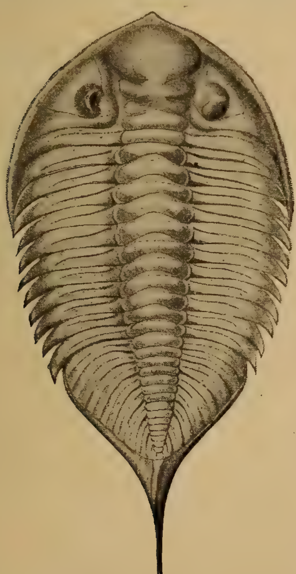


Fig. 155 Dalmanites limulurus

Genus DALMANITES Barrande

[Ety.: proper name]

(1852. *Système silurien Boh.* v. 1)

Cephalon distinctly trilobate, with a large glabella and prolonged lateral or genal spines; glabella tumid, widest in front, and divided by three well marked lateral furrows; facial suture extending from in front of the genal angles inward to the eyes and thence forward around the glabella; eyes large, with numerous distinct lenses. Thorax of 11 segments with grooved pleurae. Pygidium large, of many segments, triangular and often pointed or extended into a mucronate termination.

**Dalmanites limulurus** (Green) (Fig. 155). Phacops limulurus Hall (1852. *Pal. N. Y.* 2:303, pl. 67)

*Distinguishing characters.* Sublunate form of cephalon, pointed anteriorly; large slender genal spines; broad anterior and narrow posterior lobes of glabella; pygidium with 15 axial rings, and a long, strong mucronate spine.

Found rarely in the lower and middle but abundantly in the upper Rochester shales at Niagara. Also at Lockport and elsewhere (Hall).

Genus CALYMMENE Brongt.

[Ety.: κεκαλυμμένος, concealed]

(1822. *Hist. nat. corust. foss.* p. 7)

Body oval in outline, readily enrolled; cephalon wider than long; glabella narrowing anteriorly, conic, strongly convex, divided by three pairs of deep glabellar furrows. Facial sutures extending from just in front of the genal angles, converging forward around the eyes and reaching the anterior margin separately. Eyes small; thorax of 13 segments, with deep axial furrows; pygidium from six to 11 segments not distinctly marked off from the thorax.


Fig. 156 Calymmene blumenbachi niagarensis

**Calymmene blumenbachi niagarensis** Hall (Fig. 156) (1852. *Pal. N. Y.* 2:307, pl. 67)

*Distinguishing characters.* Semicircular outline of cephalon; glabellar lobes tuberculiform; general tapering form of thorax; axis of pygidium with about eight rings; limb grooved nearly to margin, which is thickened and rounded posteriorly.

Found rarely in the Clinton limestone lenses, and the lower Rochester shale at Niagara. Also at Lockport (Hall).

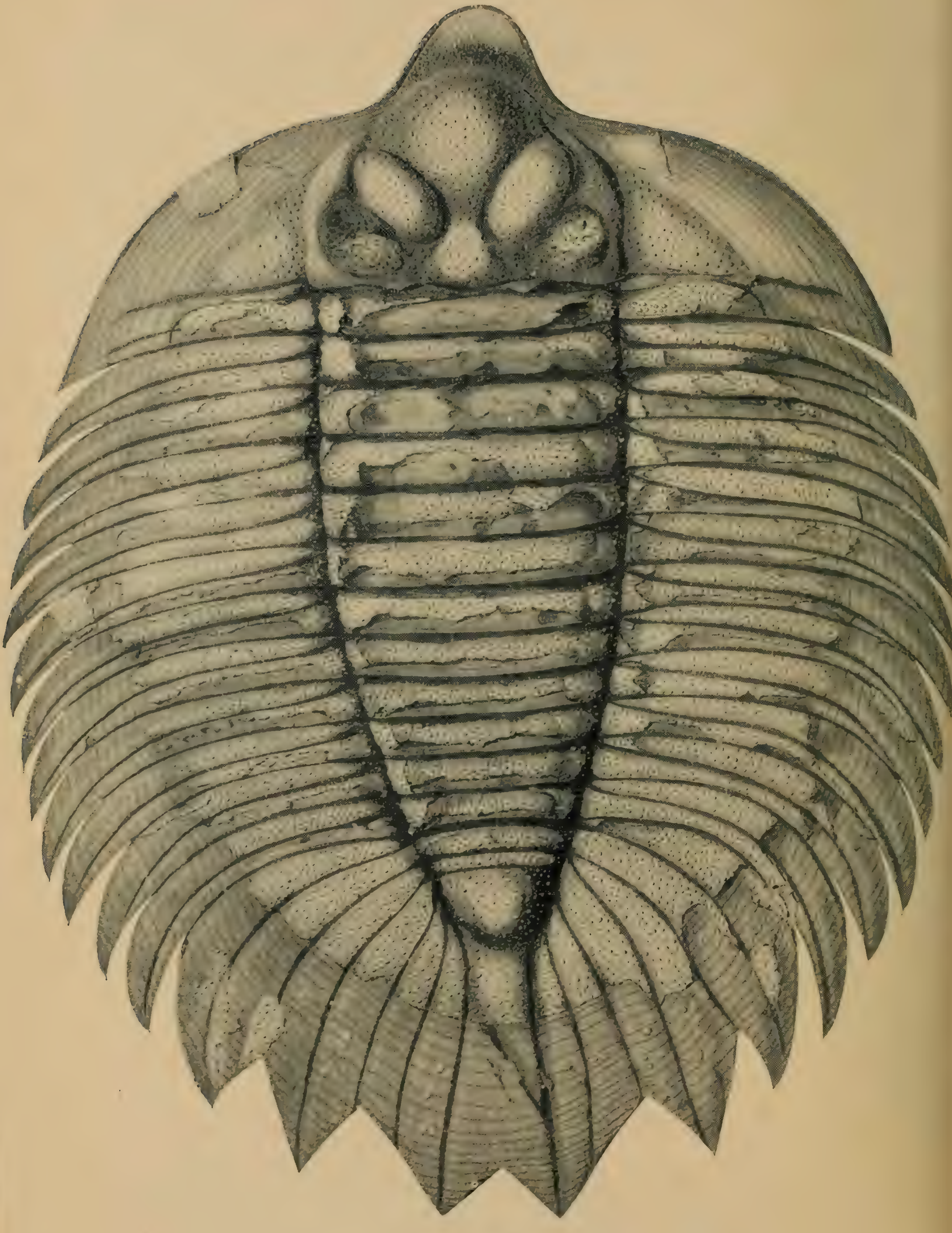
Genus LICHAS Dalman

[Ety.: mythologic name]

(1826. *Ueber die Palaeaden,* p. 71)

Trilobites with large and flat granulated shell. Cephalon small, with spinous genal angles; glabella broad, with a large, tumid anterior lobe, which dominates the smaller reniform lateral lobes on each side; eyes small; facial suture extending from the posterior

Plate 17



Lichas boltoni Bigsby; Rochester shale (After Hall)

margin obliquely inward to the eyes, and thence almost directly forward, cutting the margin separately. Thorax with nine or 10 segments and grooved and falcate pleurae. Pygidium large and flat, the segments commonly ending in spinous prolongations. Doublure very broad.

**Lichas boltoni** (Bigsby) (Plate 17) (Hall. 1852. *Pal. N. Y.* 2:311, pl. 69, 70)

*Distinguishing characters.* Large size; nasute anterior end; large central and oblique lateral lobes of glabella; scabrous surface with backward directed acute pustules; strongly striated doublure; three broad lateral lobes of pygidium, contracting to angular terminations.

Found in the lower Rochester shale at Niagara. Rare and in fragments. Common at Lockport and elsewhere (Hall).

## Genus ENCRINURUS Emmrich

[Ety.: *encrinus; οὐρά* =tail (from the resemblance of the pygidium to a crinoid stem)]

(1845. *Neues Jahrb.* p. 42)

Cephaion narrow, wider than long, tuberculated; glabella pyriform, prominent; free cheeks narrow, separated in front; eyes small, elevated, on conic prominences. Thoracic segments 11. Pygidium triangular, with numerous segments.

**Encrinurus ornatus** Hall & Whitfield (Fig. 157). Cybele punctata Hall (1852. *Pal. N. Y.* 2:297, pl. A66)

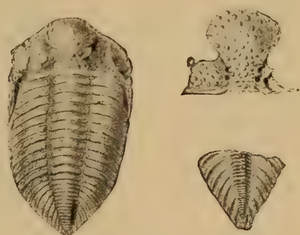


Fig. 157 Encrinurus ornatus

*Distinguishing characters.* Strongly pustulose surface of cephalon; pyriform glabella; elongate triangular pygidium, with concavity along the center of the axis, tuberculated at intervals; slender curving ridges of pygidial limb, tuberculated at intervals.

Found in the lower Clinton limestone at Niagara. Rare. Also at Lockport (Hall).

Genus BRONTEUS Goldfuss

[Ety.: mythologic name]

(1839. *Nova act. phys. med. caes. Leop. Carol. Nat. curios.* 19:360)

Dorsal shield broadly elliptic, with the cephalon less than one third the entire length; glabella rapidly expanding in front, with faint lobations. Thorax of 10 segments. Pygidium longer than cephalon or thorax, with a short axis and radiating furrows extending from it across the broad limb. Margin generally entire.

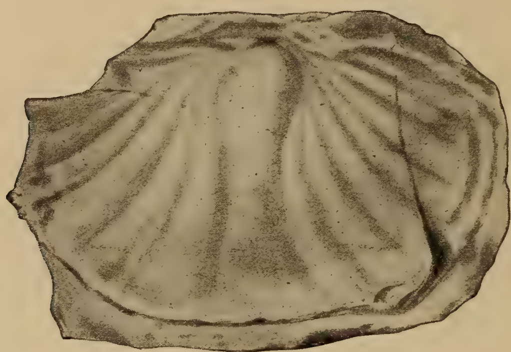


Fig. 158 Bronteus niagarensis; pygidium

**Bronteus niagarensis** Hall (Fig. 158) (1852. *Pal. N. Y.* 2:314, pl. 70)

*Distinguishing characters.* Pygidium only known; broad and somewhat semicircular; short axis and from six to nine long curving furrows or sulcations on either side of the center.

Found in "a large fragment of limestone in the Niagara river below the Canada fall" (Hall).

Order PHYLLOCARIDA Packard[1]

Crustacea with the body composed of five cephalic, eight thoracic, and two to eight abdominal segments. Head and thorax covered by a thin chitinous or semicalcareous single or bivalved shell or carapace. A narrow movable plate or *rostrum* lies in front of the caparace. Two pairs of antennae and stalked compound eyes present. Thoracic segments with soft leaf-like legs. Abdomen often ending in spiniform telson, provided with lateral spines.

[1] This section was revised by Prof. John M. Clarke, who also prepared the synopsis of species and synonymy.

## Genus CERATIOCARIS McCoy

[Ety.: κεράτιον, pod; καρίς, shrimp]

(1849. *Ann. mag. nat. hist.* ser. 2, 4:412)

Carapace consisting of a smooth, pod-shaped bivalved shell, without eye nodes. Valves of carapace elongate, subovate, or subquadrate, truncated behind. A free lanceolate rostrum occurs. Body of 14 or more segments, of which from four to seven extend beyond the carapace. Some of these have obscure branchial appendages. Telson a long, pointed spine, with two smaller lateral spines (cercopods) articulated to it.

Fig. 159 Ceratiocaris acuminata, Hall

An essentially entire specimen with the various parts in their normal position. The large bivalved carapace is folded along the back and by the breaking away of a portion of the nearer or right side the margin of the other is exposed. Near the anterior extremity are shown a pair of mandibles or "stomach-teeth." The posterior portion of the carapace is seen to inclose several of the abdominal segments and of those which project, the last is very much the longest. Of the caudal spines, three in number, but two are here shown, the long central or telson and one of the lateral or cercopods. Two thirds natural size. From a specimen in the Museum of the Buffalo society of natural sciences.

**Ceratiocaris acuminata** Hall (Fig. 159) (1859. *Pal. N. Y.* 3:422, pl. 84)

*Distinguishing characters.* Carapace large, tapering in front, broad medially and rather abruptly truncated on posterior margin. Surface with very fine, raised longitudinal lines. Penultimate segment long; telson and cercopods short.

Found in the Waterlime beds of North Buffalo.

**Ceratiocaris (Phasganocaris?) deweyi** Hall (Fig. 160)

Onchus deweyi Hall (1852. *Pal. N. Y.* 2:320, pl. 71)

*Distinguishing characters.* Large spine of telson only

known; longitudinally grooved; periodic depressions or large pits in the grooves; shown as blunt spines on the rock mold.

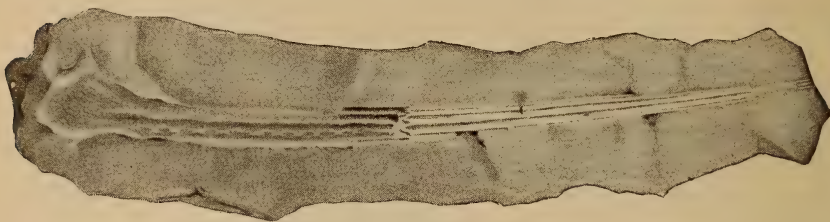


Fig. 160 Ceratiocaris (Phasganocaris ?) deweyi. Telson (reduced)

Found in the Lockport limestone at Niagara; also in the shale at Lockport (Hall).

### Order EURYPTERIDA Burmeister

The eurypterids are large Crustacea, with an elongate body composed of cephalothorax, a ringed abdomen, and a tail piece or telson. The body is covered by a chitinous epidermal skeleton, and could be cast off as in the modern horseshoe crab (Limulus). The cephalothorax is usually furnished dorsally with two large, facetted lateral eyes, and a pair of median ocelli; and ventrally with six pairs of legs. The anterior joints or rings of the abdomen bear on their under side five pairs of broad, leaf-like appendages, which are comparable to the gills and operculum of the horseshoe crab. The posterior six segments are without appendages. The legs are comparable to those of Limulus and, like them, their inner margins are furnished with stout spines which serve as teeth. The last pair of legs is generally large, and usually somewhat flattened, and ends in an oval plate. This " paddle " may have been used for swimming purposes or for purposes of anchoring. On the under or ventral surfaces of the first two abdominal segments is the genital operculum, a pair of plates meeting medially, with a median lobe attached which differs in the two sexes.

### Genus EURYPTERUS DeKay

[Ety.: εὐρύς, broad; πτερόν, wing]

(1825. *Lyc. nat. hist. N. Y. An.* 1:375)

Body elongate and narrow, often of great size. Cephalothorax one fifth or one sixth of the whole length, depressed convex, of a subquadrate outline with the anterior angles rounded, and the posterior margin slightly concave; entire margin bordered by a narrow marginal furrow. Eyes reniform, situated somewhat in front of the middle; ocelli close to the axial line. Mouth a ventral cleft. Legs

progressively increasing in length backward, the anterior pair with pincers or *chelae;* second, third and fourth pair six to seven-jointed, and covered with fine spines; fifth pair eight-jointed; posterior pair consisting of eight segments, large and powerful, with a large, subquadrate basal joint in each, and a broad terminal " paddle ". Anterior six abdominal segments occupying together about one fourth of the entire body length, short, broad and nearly uniform in shape. Succeeding six segments are ring-like, progressively decreasing in diameter, thus causing a tapering of the body. Telson long and slender.

**Eurypterus lacustris** Harlan (Hall. 1859. *Pal. N. Y.* 3:407*, pl. 81, 81A, 81B, 83B)

*Distinguishing characters.* Animal stout; anterior portion of the abdomen very broad, abruptly tapering beyond the sixth segment; penultimate segment quadrate, without lateral flanges.

Very abundant in the Waterlime of North Buffalo.

**Eurypterus remipes** De Kay (Plate 18) (Hall. 1859. *Pal. N. Y.* 3:404*, pl. 80, 80A, 83B)

*Distinguishing characters.* Animal small, with lateral body margins making broad outward curves and tapering very gradually backward. Penultimate segment slightly if at all flanged.

Occasionally in the Waterlime of North Buffalo.

**Eurypterus pustulosus** Hall (1859. *Pal. N. Y.* 3:413*, pl. 83B), Eurypterus giganteus Pohlman (*Buffalo soc. nat. sci. Bul.* 4:41)

*Distinguishing characters.* Cephalothorax large, short and very broad; eyes on the median transverse line; surface strongly pustulose.

A single specimen has been recorded from the Waterlime of North Buffalo.

**Eurypterus robustus** Hall, Eurypterus lacustis var. robustus Hall (1859. *Pal. N. Y.* 3:410*, pl. 81C)

*Distinguishing characters.* Like E. lacustris, but larger and more robust, and proportionately narrower over the anterior abdominal region.

Common in the Waterlime at North Buffalo.

**Eurypterus pachychirus** Hall (1859. *Pal. N. Y.* 3:412*, pl. 82)

*Distinguishing characters.* Similar to E. robustus; may prove identical. Terminal joints of the sixth pair of legs very broad.

Rare in the Waterlime at North Buffalo.

**Eurypterus dekayi** Hall (1859. *Pal. N. Y.* 3:411*, pl. 82)

*Distinguishing characters.* Proportionally short body; short broad carapace; anterior part of the abdomen very broad, posterior part much contracted. Penultimate segment with elongate lateral flanges.

Occasionally in the Waterlime at North Buffalo.

### Genus DOLICHOPTERUS Hall

[Ety.: δολιχός, long; πτερόν, wing]

(1859. *Pal. N. Y.* 3:414*)

Distinguished from Eurypterus by having the sixth pair of cephalothoracic legs long and narrow, with the last two joints of subequal size. Metastoma elongate heart-shaped, as in Pterygotus.

**Dolichopterus macrochirus** Hall (1859. *Pal. N. Y.* 3:414*, pl. 83, 83A)

*Distinguishing characters.* Robust, elongated body, long, straight-sided carapace, very anterior eyes; strong and thick jointed anterior appendages; extremely long sixth pair of legs.

Found in the Waterlime beds of North Buffalo.

### Genus EUSARCUS Grote & Pitt

[Ety.: εὖ, well; σάρξ, flesh (well-fleshed)]

(1875. *Buffalo soc. nat. sci. Bul.* 3:1)

Eurypterids with the anterior six abdominal segments greatly expanded, and the succeeding ones abruptly contracted. The terminal joint of the sixth pair of legs is not expanded.

**Eusarcus grandis** Grote & Pitt (*Buffalo soc. nat. sci. Bul.* 3:17)

*Distinguishing characters.* Large size, attaining a length of 2 or 3 feet. Subcylindric posterior abdominal segments.

In the Waterlime at North Buffalo.

Plate 18

Eurypterus remipes DeKay; Rondout Waterlime, Buffalo (original)

**Eusarcus scorpionis** Grote & Pitt (*Buffalo soc. nat. sci. Bul.* 3:1)

*Distinguishing characters.* Smaller than the foregoing; average length about 1 foot. Appearance strikingly scorpioid. Telson strongly curved.

In the Waterlime at North Buffalo.

Genus PTERYGOTUS Agassiz

[Ety.: *πτερύγωτός*, winged]

(1839. Murchison. *Silurian system*, p. 605)

Large, often gigantic eurypterids, with a semiovate cephalothorax, anterior marginal eyes and central ocelli. The first pair of cephalothoracic legs (pre-oral) very long, slender, terminating in large pincers or chelae, and probably prehensile in function. Behind the mouth are four pairs of slender walking legs, and behind these are the large swimming feet, which differ from those of Eurypterus in being less broadly expanded at the ends. Telson an oval plate, either terminating in a short projecting point or bilobed.

**Pterygotus macrophthalmus** Hall (1859. *Pal. N. Y.* 3:418*), Pterygotus buffaloensis Pohlman (*Buffalo soc. nat. sci. Bul.* 4:17) and Pterygotus acuticaudatus Pohlman (*Buffalo soc. nat. sci. Bul.* 4:42)

*Distinguishing characters.* Cephalothorax subquadrate or tapering anteriorly; eyes very large and high, with circular base. Chelae (pincers) with angular front end; posterior denticles on larger ramus inclined and serrate.

In the Waterlime at North Buffalo.

**Pterygotus cobbi** Hall (1859. *Pal. N. Y.* 3:417*, pl. 83B, fig. 4), Pterygotus cummingsi Grote & Pitt (*Buffalo soc. nat. sci. Bul.* 4:18)

*Distinguishing characters.* Animal large; chelae (pincers) with curved front ends and erect non-serrate denticles.

Rare in the Waterlime at North Buffalo.

**Pterygotus globicaudatus** Pohlman (*Buffalo soc. nat. sci. Bul.* 4:42)

*Distinguishing characters.* Animal rather small; surface coarsely tubercled; telson circular without median keel.

A single specimen from the Waterlime of North Buffalo.

## DISTRIBUTION OF FOSSILS IN THE SILURIC BEDS

*Synopsis of strata:*

| | | | |
|---|---|---|---|
| | Medina | 1 | Upper Medina sandstones and shales |
| | | 2 | Clinton lower shale |
| | | 3 | Clinton lower limestone (mainly lowest 4 feet) |
| | Clinton beds | 4 | Clinton upper limestone (crystalline) |
| | | 5 | Top beds of Clinton limestone |
| | | 6 | Clinton lens. Niagara gorge |
| | | 7 | Clinton lens. R. W. & O. railroad |
| | | 8 | Lowest foot of shale |
| | | 9 | Shale 3 feet above Clinton limestone |
| | | 10 | Shale 4 feet above Clinton limestone |
| | | 11 | Shale 5 feet above Clinton limestone |
| Rochester shales | Lower shale | 12 | Shale 6 to 8 feet above Clinton limestone |
| | | 13 | Shale 19 feet above Clinton limestone |
| | | 14 | Shale 25 feet above Clinton limestone |
| | | 15 | Bryozoa beds |
| | Upper shale | 16 | Upper shales |
| | | 17 | Lockport limestones |
| | | 18 | Waterlime, Buffalo |
| | | 19 | Manlius limestone |

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Plants* | | | | | | | | | | | | | | | | | | | |
| Bythotrephis gracilis | .... | rc | rc | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| B. lesquereuxi | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | r | .... |
| Arthophycus harlani | [1]c | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| Nematophycus crassus | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | r |
| *Hydrozoa* | | | | | | | | | | | | | | | | | | | |
| Dictyonema retiformis | .... | .... | .... | .... | .... | .... | .... | .... | .... | r | .... | r | .... | .... | .... | .... | .... | .... | .... |
| Stromatopora concentrica | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | c | .... | .... |
| *Anthozoa* | | | | | | | | | | | | | | | | | | | |
| Enterolasma caliculus | .... | .... | .... | .... | r | c | ? | rc | .... | c | .... | .... | .... | .... | r | .... | .... | | .... |
| Zaphrentis turbinata | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | ? | .... | .... |
| Cyathophyllum hydraulicum | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | cc |
| Chonophyllum niagarense | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| Diplophyllum caespitosum | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| Favosites venustus | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | c | .... | .... |
| F. parasiticus | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | rc | .... | .... | .... | .... |
| F. pyriformis | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| F. constrictus | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| F. niagarensis | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | c | .... | .... |
| Halysites catenulatus | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | rc | .... | .... |
| Heliolites elegans | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| H. spinipora | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| H. pyriformis | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| Cladopora seriata | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | rc | .... | .... | .... | .... |
| C. multipora | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| Striatopora flexuosa | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | rc | .... | .... | .... | .... |
| *Cystoidea* | | | | | | | | | | | | | | | | | | | |
| Caryocrinus ornatus | .... | .... | .... | .... | .... | .... | .... | .... | .... | c | .... | .... | r | c | rc | .... | .... | .... | .... |
| Callocystites jewetti | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| *Crinoidea* | | | | | | | | | | | | | | | | | | | |
| Stephanocrinus angulatus | .... | .... | .... | .... | .... | .... | .... | r | .... | c | .... | .... | .... | c | r | .... | .... | .... | .... |
| S. gemmiformis | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |

[1] rr very rare; r rare; rc moderately common; c common; cc very common.

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Crinoidea* (continued) | | | | | | | | | | | | | | | | | | | |
| Thysanocrinus liliiformis | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| Lyriocrinus dactylus | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | ? | .... | .... | .... | .... | .... |
| Glyptocrinus plumosus | .... | .... | .... | rc | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| Eucalyptocrinus decorus | .... | .... | .... | .... | .... | r | .... | .... | .... | .... | .... | rc | .... | rc | ? | .... | rc | .... | .... |
| Ichthyocrinus laevis | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | rc | .... | .... | .... | .... | .... |
| Lecanocrinus macropetalus | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| *Annelida* | | | | | | | | | | | | | | | | | | | |
| Cornulites bellistriatus | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | ? | .... | .... | .... | .... |
| *Bryozoa* | | | | | | | | | | | | | | | | | | | |
| Diploclema sparsum | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| Ceramopora imbricata | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| C. (?) incrustans | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| Chilotrypa ostiolata | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | c | rc | .... | .... | .... | .... |
| Batostomella granulifera | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | r | .... | .... | .... | .... | .... |
| Lioclema florida | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | r | .... | .... | .... | .... |
| L. aspera | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| Trematopora tuberculosa | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | c | .... | .... | .... | .... |
| T. (?) striata | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| Callopora elegantula | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | cc | .... | .... | .... | .... |
| Phylloporina asperato-striata | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | r | .... | c | .... | .... | .... | .... |
| Drymotrypa diffusa | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | r | r | .... | .... | .... | .... |
| Fenestella elegans | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | rc | .... | .... | .... | .... |
| Semicoscinium tenuiceps | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | rc | .... | .... | .... | .... |
| Polypora incepta | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | c | .... | .... | .... | .... |
| Helopora fragilis ? | cc | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| Clathropora frondosa | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| C. alcicornis | .... | .... | .... | .... | .... | .... | .... | .... | .... | r | .... | .... | .... | r | r | .... | .... | .... | .... |
| Rhinopora tuberculosa | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| Diamespora dichotoma | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | rc | .... | .... | .... | .... |
| Lichenalia concentrica | .... | .... | r | .... | .... | c | c | .... | .... | r | .... | .... | r | .... | r | .... | .... | .... | .... |
| *Brachiopoda* | | | | | | | | | | | | | | | | | | | |
| Lingula cuneata | c | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| Pholidops squamiformis | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | rc | .... | .... | .... | .... | .... |

| | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Dictyonella corallifera | | | | | | | | | | | | | | | r | | | | |
| Leptaena rhomboidalis | | | | | r | r | r | | | c | r | | rc | c | c | r | | | |
| Stropheodonta corrugata | | | | ? | | r | | | | | | | | | ? | | | | |
| S. profunda | | | c | rc | | | | | | | | | | | | | | | |
| Strophonella striata | | | | | | | | | | | | | | | r | rc | | | |
| S. (?) patenta | | | r | ? | c | r | | | | | | | | | ? | | | | |
| Plectambonites sericeus | | | r | | | | | | | | | | | | | | | | |
| P. transversalis | | | | | | rc | | r | c | c | rc | | r | | r | | | | |
| Orthothetes subplanus | | | | | rc | rc | | | | ? | | r | ? | c | rc | rc | | | |
| O. hydraulicus | | | | | | | | | | | | | | | | | | | c |
| Chonetes cornutus | | | | | | | | | | | | | | | | ? | | | |
| Orthis flabellites | | | | | r | | | | | r | | | | | ? | | | | |
| O. (?) punctostriata | | | | | | | | | | | | | | | ? | | | | |
| Orthostrophia (?) fasciata | | | | | | | | | | | | ? | | | | | | | |
| Dalmanella elegantula | | | | | | rc | | | c | rc | | | | r | cc | | | | |
| Rhipidomella hybrida | | | | | | | | | | | | | | rc | c | r | | | |
| R. circulus | | | ? | | | | | | | | | | | | | | | | |
| Scenidium pyramidale | | | | | | | | | | | | | | | | | | | |
| Anastrophia interplicata | | | | | | r | | | ? | | | | ? | r | rc | | | | |
| A. brevirostris | | | | | | | | | | | | ? | | | | | | | |
| Pentamerus oblongus | | | | rr | | | | | | | | | | | | | | | |
| Barrandella fornicata | | | | rc | | | | | | | | | | | | | | | |
| Rhynchotreta cuneata americana | | | | | | rc | r | | | r | | | rc | rc | c | r | | | |
| Camarotoechia obtusiplicata | | | | | | | | | | r | | | | | ? | | | | |
| C. neglecta | | | rc | | | rc | r | | | | | | rc | r | c | rc | | | |
| C. acinus | | | | rc | | | | | | | | | | | | | | | |
| Rhynchonella robusta | | | | | r | | | | | | | | | | | | | | |
| R. (?) bidens | | | | | | | | | | | | | | | | | | | |
| R. (?) bidentata | | | | | | | | | | | | | | | | | | | |
| Atrypa reticularis | | | | cc | c | rc | r | r | r | c | | r | | r | rc | | | | |
| A. nodostriata | | | | | | c | rc | rc | r | rc | | | | rc | cc | | | | |
| A. rugosa | | | | r | | rc | ? | r | | rc | | | | rc | rc | | | | |
| Cyrtina pyramidalis | | | | | | | | | | | | | | | | | | | |
| Spirifer radiatus | | | | rc | rc | c | r | r | | c | | r | rc | r | rc | | | | |
| S. niagarensis | | | | | rc | c | | r | rc | c | r | c | r | c | c | | | | |
| S. crispus | | | | | | r | | | rc | r | r | | | c | cc | | | | |
| S. crispus corallinensis | | | | rc | | | r | | | rc | | | | | | | | | |
| S. eriensis | | | | | | | | | | | | | | | | | | | rc |
| S. (Delthyris) sulcatus | | | | | | r | r | | | r | | | | rc | rc | | | | |

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Brachiopoda* (continued) | | | | | | | | | | | | | | | | | | | |
| Homoeospira apriniformis | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| Trematospira camura | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | c | .... | .... | .... | .... |
| Whitfieldella nitida | .... | .... | .... | .... | .... | cc | rc | .... | .... | rc | .... | rc | r | rc | c | .... | .... | .... | .... |
| W. nitida oblata | .... | .... | .... | .... | rr | cc | .... | rc | .... | c | .... | rc | .... | c | rc | .... | .... | .... | .... |
| W. oblata | r | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| W. intermedia | .... | .... | .... | .... | .... | c | .... | rc | .... | ? | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| W. cylindrica | .... | .... | .... | .... | .... | .... | .... | .... | .... | r | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| W. sulcata | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | rc |
| W. rotundata | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | r |
| W. laevis | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | rc |
| Hyattella congesta | .... | .... | r | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| Anoplotheca hemispherica | .... | c | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| A. plicatula | .... | .... | cc | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| *Pelecypoda* | | | | | | | | | | | | | | | | | | | |
| Pterinea emacerata | .... | ? | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | r | c | .... | .... | .... |
| Liopteria (?) subplana | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | r | .... | .... | .... | .... | .... | .... | .... |
| Lyriopecten (?) orbiculoides | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | rr | .... | .... |
| Modiolopsis orthonota | c | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| M. primigenia | rc | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| Modiolopsis sp | .... | .... | .... | .... | .... | .... | r | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| *Gastropoda* | | | | | | | | | | | | | | | | | | | |
| Platyceras niagarense | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | ? | .... | .... | .... | .... |
| P. angulatum | .... | .... | .... | .... | .... | .... | .... | .... | .... | r | .... | .... | .... | r | rc | .... | .... | .... | .... |
| Diaphorostoma niagarense | .... | .... | .... | .... | .... | r | .... | .... | .... | r | .... | r | .... | rc | c | r | .... | .... | .... |
| Pleurotomaria littorea | ? | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| P. pervetusta | rc | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| Bucania trilobata | ? | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| *Conularida* | | | | | | | | | | | | | | | | | | | |
| Conularia niagarensis | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |

| | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Cephalopoda* | | | | | | | | | | | | | | | | | | | |
| Orthoceras multiseptum | ? | | | | | | | | | | | | | | | | | | |
| O. annulatum | | | | | | | rc | | | | | | | | | | r | | |
| O. medullare | | | | | | | r | | | | | | | | | | r | | |
| Cyrtoceras subcancellatum | | | | | | | | | | | | | | | | | | | |
| Gomphoceras sp | | | | | | | | | | | | | | | | | | | r |
| Trochoceras gebhardi | | | | | | | | | | | | | | | | | | | |
| *Ostracoda* | | | | | | | | | | | | | | | | | | | |
| Isochilina cylindrica | r | | | | | | | | | | | | | | | | | | |
| Leperditia scalaris | | | | | | | | | | | | | | | | | | | c |
| Bollia symmetrica | | | | | | | | | | | | | | | ? | | | | |
| Aechmina spinosa | | | | | | | | | | | | | | | ? | | | | |
| *Trilobita* | | | | | | | | | | | | | | | | | | | |
| Homalonotus delphinocephalus | | | | | | | | | | | | | | r | | c | | | |
| Illaenus ioxus | | | | | | c | cc | | | r | | r | | | r | | | | |
| Dalmanites limulurus | | | | | | | | | | | | r | r | | r | cc | | | |
| Calymmene blumenbachi niagarensis | | | | | | r | | | | | | | | | r | ? | | | |
| Lichas boltoni | | | | | | | | | | | | | | r | | | | | |
| Encrinurus ornatus | | | r | | | | | | | | | | | | | | | | |
| Bronteus niagarensis | | | | | | | | | | | | | | | | | r | | |
| *Phyllocarida* | | | | | | | | | | | | | | | | | | | |
| Ceratiocaris acuminata | | | | | | | | | | | | | | | | | | rc | |
| C. deweyi | | | | | | | | | | | | | | | | | r | | |
| *Eurypterida* | | | | | | | | | | | | | | | | | | | |
| Eurypterus lacustris | | | | | | | | | | | | | | | | | | cc | |
| E. remipes | | | | | | | | | | | | | | | | | | rc | |
| E. pustulosus | | | | | | | | | | | | | | | | | | rr | |
| E. robustus | | | | | | | | | | | | | | | | | | c | |
| E. pachychirus | | | | | | | | | | | | | | | | | | r | |
| E. dekayi | | | | | | | | | | | | | | | | | | rc | |
| Dolichopterus macrochirus | | | | | | | | | | | | | | | | | | rc | |
| Eusarcus grandis | | | | | | | | | | | | | | | | | | rc | |
| E. scorpionis | | | | | | | | | | | | | | | | | | rc | |
| Pterygotus macrophthalmus | | | | | | | | | | | | | | | | | | rc | |
| P. cobbi | | | | | | | | | | | | | | | | | | r | |
| P. globicaudatus | | | | | | | | | | | | | | | | | | rr | |

*Chapter 5*

# POST-PLIOCENE FOSSILS OF THE NIAGARA RIVER GRAVELS

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The post-Pliocene shells in the gravel beds of the Niagara river have long been known, but never before been fully described. The localities at which shell-bearing gravels have thus far been found are Goat island, Prospect park, Queen Victoria park, Muddy creek, whirlpool (both sides of the river), and at Foster's flats. The shells occur, generally, intimately mixed with the sand and gravel, showing that they were transported to the present localities by currents and eddies. The same action, taking place in recent times, may be witnessed at the lower end of Goat island, where the dividing water washes the shells into the pockets and crevasses in the rock.[2]

The following table shows the distribution of these shells in the various deposits, and also where these forms may be found living today.

| NAME OF SPECIES | Goat island | Prospect park | Queen Victoria park | Muddy creek | Whirlpool, American side | Whirlpool, Canadian side | Foster's flats | Living in Niagara river | Living elsewhere |
|---|---|---|---|---|---|---|---|---|---|
| **Gastropoda** | | | | | | | | | |
| 1 Pleurocera subulare Lea | x | ---- | ---- | ---- | ---- | ---- | ---- | x | ---- |
| 2 Goniobasis livescens (Menke) | x | x | x | x | x | x | ---- | x | ---- |
| 3 G. livescens niagarensis (Lea) | x | ---- | ---- | ---- | ---- | ---- | ---- | x | ---- |
| 4 G. haldemani Tryon | x | ---- | ---- | ---- | ---- | ---- | ---- | ---- | *c* |
| 5 Amnicola limosa (Say) | x | ---- | ---- | ---- | ---- | ---- | x | ---- | ---- |
| 6 A. letsoni Walker | x | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- |
| 7 Bythinella obtusa (Lea) | x | ---- | ---- | ---- | ---- | ---- | ---- | ---- | *b* |
| 8 Pomatiopsis lapidaria (Say) | ---- | ---- | ---- | ---- | ---- | x | x | x | ---- |
| 9 Valvata tricarinata Say | x | ---- | ---- | ---- | ---- | ---- | x | x | ---- |
| 10 V. sincera Say | x | ---- | ---- | ---- | ---- | ---- | ---- | ---- | *a* |
| 11 Campeloma decisa Say | x | ---- | ---- | ---- | ---- | ---- | x | ---- | ---- |
| 12 Limnaea columella Say | x | ---- | ---- | ---- | ---- | ---- | ---- | ---- | *a* |
| 13 L. desidiosa Say | x | ---- | ---- | ---- | ---- | x | x | ---- | ---- |
| 14 L. catascopium Say | x | ---- | ---- | ---- | ---- | x | x | ---- | ---- |
| 15 Physa heterostropha Say | x | ---- | ---- | ---- | ---- | x | x | ---- | ---- |
| 16 Planorbis bicarinatus Say | x | ---- | ---- | ---- | ---- | ---- | x | ---- | ---- |
| 17 P. parvus Say | x | ---- | ---- | ---- | ---- | ---- | x | ---- | ---- |

*a* Lime lake.
*b* Chippewa creek.
*c* Living, but not within a radius of 50 miles.

[1] I wish to acknowledge here my obligations to Prof. Henry A. Pilsbry, Mr Bryant Walker and Dr V. Sterki, for valuable assistance and advice given in the preparation of this chapter.

[2] *See also* Chapter 2, Goat island gravels.

| NAME OF SPECIES | Goat island | Prospect park | Queen Victoria park | Muddy creek | Whirlpool, American side | Whirlpool, Canadian side | Foster's flats | Living in Niagara river | Living elsewhere |
|---|---|---|---|---|---|---|---|---|---|
| **Pelecypoda** | | | | | | | | | |
| 18 Sphaerium striatinum (Lam.) | x | x | x | .... | x | ...... | x | x | .... |
| 19 S. stamineum (Conrad) | x | x | ...... | .... | ...... | x | .... | x | .... |
| 20 Pisidium virginicum Bourg. | x | .... | ...... | .... | ...... | ...... | .... | ...... | *b* |
| 21 P. compressum Prime | x | .... | ...... | .... | ...... | ...... | .... | ...... | *b* |
| 22 P. abditum Haldeman | x | .... | ...... | .... | ...... | ...... | .... | ...... | *a* |
| 23 P. ultra-montanum Prime | x | .... | ...... | .... | ...... | ...... | .... | ...... | *a* |
| 24 P. scutellatum Sterki | x | .... | ...... | .... | ...... | ...... | .... | ...... | *a* |
| 25 Lampsilis rectus (Lam.) | x | .... | ...... | .... | ...... | ...... | .... | x | .... |
| 26 L. ellipsiformis (Conrad) | .... | x | ...... | .... | ...... | ...... | .... | x | .... |
| 27 Alasmidonta calceola (Lea) | x | .... | ...... | .... | ...... | ...... | .... | x | .... |
| 28 A. truncata (Wright) | x | .... | ...... | .... | ...... | ...... | .... | x | .... |
| 29 Unio gibbosus Barnes | x | x | x | x | ...... | x | x | x | .... |
| 30 Quadrula solida (Lea) | .... | x | ...... | .... | ...... | ...... | .... | x | .... |
| 31 Q. coccinea (Conrad) | x | x | x | x | ...... | x | x | x | .... |

*a* Lime lake.
*b* Chippewa creek.
*c* Living, but not within a radius of 50 miles.

## Class GASTROPODA Cuvier

### Genus PLEUROCERA Rafinesque. 1819

Shell lengthened and conical, aperture moderately prolonged into a short spout or canal in front. The columella is not thickened.

**Pleurocera subulare** Lea (Fig. 161) (*Philos. soc. Trans.* 4:100)

Shell large and heavy, elevated and turreted, having an acute apex; nine to 11 whorls, flat, shouldered at the suture, which is impressed; body whorl surrounded by three ridges, the middle being the most prominent; aperture small, lip thin, folding back over the columella and covering the umbilical tract.

Locality. Goat island.

Fig. 161 Pleurocera subulare

### Genus GONIOBASIS Lea. 1862

Shell heavy, elongated or ovate, aperture plain, slightly angulated in front.

**Goniobasis livescens** (Menke) Tyron 1873 (Fig. 162). Melania livescens Menke (1830. *Syn. meth.* p. 135)

Goniobasis livescens Tryon (1873. *Smith. Misc. coll. no.* 253, p. 248)

Fig. 162 Goniobasis livescens

Shell oblong and ovate; six or seven whorls; early volutions slightly keeled; spire acute; sutures impressed; whorls convex and crossed by plainly marked growth lines; lip moderately thin, and thin callous on the columella.

This is the most common of all the shells occurring in these deposits along the Niagara river; it is subject to great variation.

Localities. Goat island, Prospect park, Whirlpool, etc.

**Goniobasis livescens** var. **niagarensis** (Lea) Tryon 1873 (Fig. 163). Melania niagarensis Lea (1841. *Philos. soc. Phil. Proc.* 2:12). Goniobasis livescens var. niagarensis Tryon (*Smith. Misc. coll.* no. 253, p. 248)

Shell conic, obtuse, thick and smooth; spire short, whorls five or six, surrounded by a sharp keel, which clearly marks the suture; aperture elliptic; lip thin; columella slightly calloused.

Fig. 163 Goniobasis livescens *var.* niagarensis

Prof. H. A. Pilsbry, who examined these shells, writes: "This remarkable form differs from G. livescens, and var. niagarensis, in the persistence of the peripheral keel to the adult stage, producing a shell contour similar to Anculosa carinata; it has not hitherto been described or noticed in conchological literature, and would be entitled to specific rank were it not connected by intermediate forms with var. niagarensis".

Locality. Goat island.

Fig. 164 Goniobasis haldemani

**Goniobasis haldemani** Tryon 1865 (Fig. 164). G. haldemani Tryon. (1865. *Am. jour. conch.* 1:38)

Shell elongated, narrow and rather thin; eight or nine whorls, which are flat, smooth and separated by a slightly impressed suture; aperture small, subrhomboidal; lip thin, moderately incurved on the columellar side.

This graceful shell is very scarce and is not represented in the recent fauna.

Locality. Goat island.

Genus AMNICOLA Gould & Haldeman. 1841

Shell small, short, subglobular, and ovate; spire obtuse; shell smooth, thin and perforate; aperture ovate; lip thin; operculum corneous.

**Amnicola limosa** (Say) Hald. 1844. Paludina limosa Say (1817. *Acad. nat. sci. Phil. Jour.* 1:125). Amnicola limosa Haldeman (1844. *Monograph* pl. 1, fig. 5, 6)

Shell small and conic; whorls four, rapidly diminishing; apex acute, suture deep; umbilicus narrow and deep; surface smooth; recent specimens show growth lines; aperture oval, slightly angulated at the junction of the body whorl; lip simple.

Found in the gravel pit on Goat island.

**Amnicola letsoni** Walker 1901 (Fig. 165)

A. letsoni Walker (Feb. 1901. *Nautilus*)

Shell small, elevated and thick; whorls four or five, more or less flattened, and inclined to be shouldered; suture deep; spire short, less than one third the entire length; apex obtuse; aperture small and oval, angled above, rounded below, flattened on the parietal margin; lip thick and free from contact with the body whorl.

Fig. 165 Amnicola letsoni x3

Locality. Goat island.

In his notes Mr Walker says: "Amnicola sheldoni Pils. is the only species with which this can be compared. The present species is to be distinguished by its flattened, shouldered whorls, deeper suture and more acuminate spire. Six mature examples were found, which, though differing somewhat in the relative proportions of length and width, are as a whole quite uniform. In four of them the peristome is distinctly separated from the body whorl; in one, while continuous, it is so close as to be almost adnate, while in the remaining specimens the parietal margin, although somewhat broken, seems to have been appressed to the body whorl for a short distance. Associated with these specimens were two other examples quite similar, but much more cylindrical in the outline, less solid, and with the aperture less angled posteriorly. Neither is quite mature, judging from the thinness of the lip. In view of the considerable variation in these particulars in other well-known species of the genus, such as Amnicola lustrica Pils., and of the few specimens now at hand, it is not deemed advisable at the present time to do more than call attention to the fact."

What may prove to be other species of Amnicola has been found, but too badly worn to justify description.

Genus BYTHINELLA Moquin-Tandon. 1855

Shell elongated and pyriform; imperforate; apex obtuse; aperture oval; lip simple; operculum corneous.

**Bythinella obtusa** (Lea) Binney 1865 (Fig. 166). Paludina obtusa Lea (1844. *Philos. soc. Phil. Trans.* 9:13). Bythinella obtusa Binney (1865. *Smith. Misc. coll.* no. 144, p. 70)

Fig. 166 Bythinella obtusa. x3

Shell small, subcylindric, comparatively thin; five whorls; spire very short, giving the shell a truncated appearance; apex obtuse; sutures well defined; delicate growth lines may be seen with a lens; the aperture is small and round; the umbilicus narrow and deep.

Found in the Goat island gravel pits.

Genus POMATIOPSIS Tryon. 1862

Animal with a broad, short foot, and short pointed tentacles. Shell thin and smooth, having a produced spire; aperture oval, and provided with an operculum.

**Pomatiopsis lapidaria** (Say) Tryon 1862 (Fig. 167). Cyclostoma lapidaria Say (1817. *Acad. nat. sci. Phil. Jour.* 1:13). Pomatiopsis lapidaria Tryon (1862. *Acad. nat. sci. Phil. Proc.* p. 452)

Shell conic; spire high, seven whorls, well rounded and transversely wrinkled; sutures impressed; aperture rounded and about one third the length of the shell; subumbilicate.

Fig. 167 Pomatiopsis lapidaria. x3

Found at Foster's flats. This species is not found in any of the other deposits.

The locality at Foster's flats, where this little shell is found, is just below the old fall. At the present time, the only locality for P. lapidaria thus far discovered along the river is on the rocks in the constant rain of spray, below the present fall.

Genus VALVATA Müller. 1842

Animal with a bilobed foot, simple mantle and feather-like gills, protected by a long, slender respiratory lobe. The shell is discoidal, has a deep umbilicus and is provided with an operculum.

**Valvata tricarinata** Say 1822 (Fig. 168). C y c l o s t o m a t r i c a r i n a t a Say (1817. *Acad. nat. sci. Phil. Jour.* 1:13). V a l v a t a t r i c a r i n a t a Say (1822. *Acad. nat. sci. Phil. Jour.* 2:173)

Shell with four whorls, bearing three prominent carinae; growth lines low and indistinct; suture well impressed; umbilicus large and deep, showing the whorls to the apex; revolving lines or carinae placed one on the upper edge, one on the lower edge, and one on the base.

Fig. 168 Valvata tricarinata. x3

Found in Goat island gravel pits. As a recent shell, it is very common in the river and its tributary streams.

**Valvata sincera** Say (Fig. 175). V a l v a t a s i n c e r a Say (*Long's expedition*, p. 264, pl. 15, fig. 11)

Fig. 169 Valvata sincera. x3

This shell is more globose than the foregoing and has four whorls, rounded and finely wrinkled; aperture round, not diminishing in thickness at the point of contact; umbilicus large, exhibiting the whorls to the apex.

Found associated with V. t r i c a r i n a t a in the gravel on Goat island.

V. s i n c e r a is not found in Niagara river at the present time, nor is it found in the immediate vicinity. Lime lake is the only locality within a radius of 50 miles known to the writer for this species.

### Genus CAMPELOMA Rafinesque

Animal with a large foot; head of moderate size, situated somewhat back from the end of the foot. Shell thick and solid, oval; spire somewhat produced; surface smooth and rounded; lip simple and continuous; columellar side entirely covers the umbilicus.

**Campeloma decisa** Say 1817 (Fig. 170). L i m n a e a d e c i s a Say (1817. *Nich. enc. Am. ed.* 1)

Fig 170 Campeloma decisa

Shell imperforate or nearly so, oval with a smooth surface; whorls five, rounded, last whorl slightly shouldered at the suture; aperture oval; lip simple with a callus on the columellar side.

Locality. Goat island gravel pit.

### Genus LIMNAEA Lamarck. 1798

Animal provided with a broad head and flattened triangular tentacles; mantle thickened in front; foot broad and flat. Shell dextral, spire oblong; aperture large and wide; the outer lip is simple, the inner has a fold on the columella.

This genus is well represented among the recent shells in this vicinity. They may be found in all the streams tributary to the Niagara.

**Limnaea columella** Say 1817 (Fig. 171). L. columella Say (1817. *Acad. nat. sci. Phil. Jour.* 1:14)

Fig. 171 Limnaea columella

This is a very thin, fragile shell having four whorls, rapidly diminishing, separated by a distinct but not deeply impressed suture; aperture large, more than one half the length of the shell; lip simple, and surface longitudinally wrinkled by growth lines.

Locality. Goat island gravel pits.

Only one specimen of this species was found, leading me to believe that it was an uncommon shell in early post-Pliocene times, as it is at the present time, Lime lake being the only locality in this vicinity where the recent shell occurs.

Fig. 172 Limnaea desidiosa x3

**Limnaea desidiosa** Say 1821 (Fig. 172). L. desidiosa Say (1821. *Acad. nat. sci. Phil. Jour.* 2:169) Shell oblong and subconic, with five very convex whorls; suture deeply impressed; last whorl slightly swollen; slight growth lines visible with a lens.

Localities. Goat island, Whirlpool and Foster's flats.

This is the most common Limnaea found in these deposits.

**Limnaea catascopium** Say 1817 (Fig. 173). L. catascopium Say (1817-19. *Nich. enc. Am. ed.* p. 11, fig. 3. 1834. *Am. conch.* v 6. pl. v, fig. 2; 1841. Haldeman. *Monograph* 6, pl. 1)

Fig. 173 Limnaea catascopium

Shell thin, sculptured spirally by delicate lines, giving it a very beautiful appearance under the lens; growth lines heavy at the suture, making slight plications; whorls four or five, decreasing to an acute apex; aperture about three quarters the length of the shell; lip simple, folding back on the columellar side and leaving a narrow umbilicus.

Localities. Goat island, Whirlpool and Foster's flats.

## Genus PHYSA Draparnaud

The animal of Physa is triangular in general shape; tentacles slender and setaceous; mantle covers part of the shell, the margin folding over the body whorl in a fringe. The shell is sinistral, thin, with an acute spire; body whorl large, inflated and the aperture large and oval; lip simple.

**Physa heterostropha** Say 1821 (Fig. 174). Limnaea heterostropha Say (1817-19. *Nich. enc. Am. ed.* pl. 1, fig. 6). Physa heterostropha Say (1821. *Acad. nat. sci. Phil. Jour.* 2:172)

Shell oval and smooth, sinistral; whorls four, the first large, the others very small and terminating in an acute apex; aperture large and oval, about half the length of the shell; outer lip a little thickened, inner lip folded back on the columella, forming a slight callus.

Fig 174 Physa heterostropha. x3

Localities. Goat island, Whirlpool and Foster's flats.

## Genus PLANORBIS Guettard. 1756

The animal of Planorbis has a broad foot, and long slender tentacles. The shell is dextral and discoidal; the spire depressed, and the whorls numerous and visible on both sides; the aperture is transversely oval, with a thin lip.

**Planorbis bicarinatus** Say 1817 (Fig. 175). Planorbis bicarinatus Say (1817-19. *Nich. enc. Am. ed.* pl. 1, fig. 4)

Fig. 175 Planorbis bicarinatus. x2

Shell sinistral; sharply carinated on both sides; all the whorls may be seen from either side; aperture vaulted above, angulated below; surface wrinkled with growth lines at regular distances and surrounded by fine revolving striae.

Locality. Found only in the gravel on Goat island.

**Planorbis parvus** Say 1817 (Fig. 176). P. parvus Say (1817-19. *Nich. enc. Am. ed.* pl. 1, fig. 5). P. parvus Say (1865. *Smith. Misc. coll.* no. 144, p. 133)

Shell small, with four whorls crossed by wrinkles or growth lines; concave above and below; body whorl slightly swollen; mouth oblique, with the lip simple.

Fig. 176 Planorbis parvus. x2

Locality. Goat island and Foster's flats.

## Class PELECYPODA Goldfuss

## Genus SPHAERIUM Scopoli. 1777

General shape of the animal oval, margins plain, united behind and ending in two short siphons, which are joined at their base; mouth oval and small; gills broad and unequal, the inner ones largest; the foot tongue-shaped, triangular, flattened and very extensible. Shell thin, oval, often inflated, with prominent beaks;

hinge margin narrow, cardinal teeth very small or rudimentary, one of them more or less bifurcated, one cardinal tooth in the right and two oblique ones in the left valve; lateral teeth compressed and lamelliform, the anterior shortest; ligament short; margins plain; muscular impressions scarcely apparent and pallial line simple.


Fig. 177 Sphaerium striatinum. x3

**Sphaerium striatinum** (Lam.) Prime 1865 (Fig. 177). Cyclas striatina Lamarck (1818. *Animaux sans vertèbres*, 5:560). Sphaerium striatinum Prime (1865. *Smith. Misc. coll.* no. 145, p. 37)

Shell slight, moderately elongated, somewhat compressed, and inequilateral; anterior margin rounded; beaks full, not much raised and not sculptured; sulcations slight and irregular; hinge line curved; cardinal teeth small, double, and of the same size; lateral teeth larger, but not very prominent.

Localities. Found in all the deposits on Goat island, Foster's flats, etc.

This little bivalve is very common in the river at the present time. It is not difficult to understand how these shells were deposited, if one studies the life and habits of the recent forms. The streamlets passing among the rocks that form the Dufferin islands will be found to contain hundreds of these small shells. The bottoms of the pools formed by eddies are white with the accumulation of dead shells, in such quantities that they may be taken up by the shovelful.

**Sphaerium stamineum** (Conr.) Prime 1865 (Fig. 178). Cyclas staminea Conrad (1834. *Am. jour.* 25:342). Sphaerium stamineum Prime (1865. *Smith. Misc. coll.* no. 145, p. 38)

Shell oval, full and inequilateral; anterior end abrupt; posterior end somewhat distended; beaks full, prominent and sometimes sculptured; striae heavier than in the foregoing species; hinge margin more curved; cardinal teeth double, and not very distinct; lateral teeth stronger.


Fig. 178 Sphaerium stamineum. x2

In this, as in the preceding species, specimens frequently occur in which the hinge is reversed.

Localities. Goat island, Prospect park, and near the Whirlpool.

Recent species of this interesting group of fresh-water bivalves abound in Niagara river and its tributaries. While they prefer the soft mud at the bottom, they are frequently found attached to the

lower side of branches and floating debris, where they may be seen moving about by means of the long, flexible foot.

Genus PISIDIUM Pfeiffer. 1821

The animal closely resembles that of the foregoing genus, but the siphons are united to the end, those in Sphaerium being separated and more elongated. The shell is trigonal or rounded oval; the cardinal teeth are very small and double, at times they are united and are situated directly under the beaks; the lateral teeth are elongated, lamelliform, double in the right valve, single in the left; the ligament is always on the shorter side.

**Pisidium virginicum** (Gmelin) Bourg. 1853 (Fig. 179). Tellina virginica Gmelin (1788. ? p. 3236, pl. 159, fig. 15). Pisidium virginicum Bourg. (1853. *Am. Malac.* 1:53)


Fig. 179 Pisidium virginicum. x3

This is the largest Pisidium found in this region; it is thick and oblique; anterior side very much longer, narrower and more rounded than the posterior side, the latter being much broader and well rounded; beaks prominent and posterior; striae coarse; hinge broad and with two large cardinal teeth; laterals small and delicate.

Locality. Goat island.


Fig. 180 Pisidium compressum. x5

**Pisidium compressum** Prime 1851 (Fig. 180). P. compressum Prime (1851. *Bost. soc. nat. hist. Proc.* 4:164)

Shell solid, triangular and somewhat attenuated at the beaks, which are inflated; anterior side longer, narrower and more produced than the posterior; the latter subtruncate; beaks not much inflated; striae distinct and regular; hinge thick, having strong, short teeth; cardinals compressed; laterals placed at an obtuse angle with the hinge.

Locality. Goat island.

**Pisidium abditum** Hald. 1841 (Fig. 181). P. abditum Haldeman (1841. *Acad. nat. sci. Phil. Proc.* 1:53)


Fig. 181 Pisidium abditum. x2

Shell rounded, oval and very thin, somewhat elongated, beaks small, not inflated and placed posteriorly; surface smooth, the growth lines being indistinct; hinge nearly straight; cardinal teeth small, the anterior tooth being larger and more prominent; the lateral teeth not much elongated.

Locality. Goat island.

**Pisidium ultramontanum** Prime 1865 (Fig. 182). P. ultramontanum Prime (1865. *Smith. Misc. coll.* no. 145, p. 75)


Fig. 182 Pisidium ultramontanum. x3

Shell solid, oval or suborbicular, and remarkably compressed; anterior side much produced between the extremity of the lateral teeth and the junction with the basal margin; posterior margin well rounded; beaks small and only slightly raised above the outline of the shell; the striae very fine and even, and the hinge line straight.

Locality. Goat island.

**Pisidium scutellatum** Sterki. 1896 (Fig. 183). P. scutellatum Sterki (1896. *Nautilus*, 10:66)

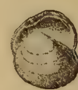
Fig. 183 Pisidium scutellatum. x3

Shell high, oblique, slanting downward anteriorly, well rounded and rather strongly inflated; beaks posterior, rather large and prominent, margins well curved, the surface polished, having irregular growth lines; the hinge fine and short; cardinal teeth lamellar, the one in the right valve moderately curved, its posterior end being thickest; the inferior in the left valve curved; the superior almost straight; the lateral teeth very short, abrupt, pointed and thin, projecting somewhat into the cavity of the shell.

Locality. Goat island.

Genus LAMPSILIS Rafinesque. 1820

Shell inflated, rather thin, and shining, sometimes having a posterior ridge; sculpture coarse at beaks.

**Lampsilis rectus** (Lam.) Smith 1899 (Fig. 184). Unio

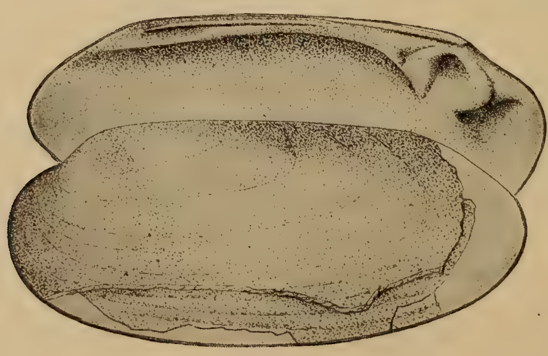
Fig. 184 Lampsilis rectus

recta Lamarck (1819. *Animaux sans vertèbres*, 6:74) Lampsilus rectus Smith (1899. *U. S. fish com. Bul.* p. 290)

Shell large, oblong, ovate, compressed and comparatively thin; surface regularly and smoothly marked by growth lines; anterior end rounded, posterior end slightly angulated; dorsal margins straight or nearly so, hollowed a little back of the beaks; ventral margin straight; adductor muscle impressions well defined; cardinal teeth not large, two on the left valve and one on the right; lateral teeth delicate; beak, in present specimen, smooth, slightly sculptured in recent specimens.

Locality. Goat island.

**Lampsilis ellipsiformis** (Conrad) Simpson 1900 (Fig. 185).
Unio ellipsiformis Conrad (1836. *Monograph*, 8:60)
Unio spathulatus Lea (1845. *Am. philos. soc. Proc.* 4:164)
Lampsilis ellipsiformis Simpson (1900. *U. S. nat. mus. Proc.* 22:557)

Shell oblong, very compressed, rounded both anteriorly and posteriorly; surface slightly roughened by the growth lines; dorsal

Fig. 185 Lampsilis ellipsiformis

margins curved; ventral margins angulated toward the posterior end; anterior adductor muscle impression deep and triangular, slightly pitted; posterior muscle scar broad and oval, showing the ray-like growth lines; hinge area broad and flat; teeth strong, both cardinal and lateral, there being two cardinal teeth in each valve, two lateral teeth in the left valve and one in the right; hinge area between the cardinal and lateral teeth broad and very slightly undulated; pallial line well impressed; beaks low, showing no sculpture, though recent specimens show delicate waves or ridges.

Locality. Found in Prospect park by Prof. Irving P. Bishop.

## Genus ALASMIDONTA Say. 1818

The shell is ovate, solid and inflated, shining, with strong beak sculpture. Cardinal teeth thick and strong; the laterals are short, sometimes not present.

**Alasmidonta calceola** (Lea) Simpson 1900 (Fig. 186). Unio calceolus Lea (1830. *Philos. soc. Trans.* 3:265). Alasmidonta calceola Simpson (1900. *U. S. nat. mus. Proc.* 22:668)

Fig. 186 Alasmidonta calceola

Shell small, solid and inflated; surface smooth; anterior end rounded; posterior end triangular; dorsal margin oval to the umbo, whence it has a deep inward curve, back of and under the beak; ventral margin straight; muscle impressions deep and well defined; pallial line clear; beaks prominent, inflated, more or less sculptured.

Locality. Goat island.

**Alasmidonta truncata** (Wright) Simpson 1900 (Fig. 187). Margaritana marginata var. truncata Wright (1898. *Nautilus,* 11:124). Alasmidonta truncata Simpson (1900. *U. S. nat. mus. Proc.* 22:671)

Shell elongated, quadrangular and heavy; surface marked by distinct growth lines, which are crossed by transverse wrinkles on the posterior slope; posterior end angulated; anterior end rounded; dorsal margin curved outward at the umbo; ventral margin straight or nearly so; muscular impressions deep, particularly the anterior adductor; pallial line distinct; beaks large, prominent and incurved,

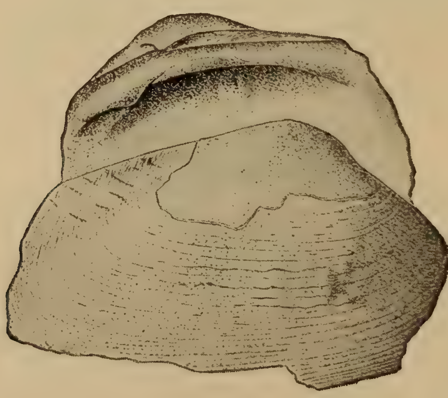

Fig. 187 Alasmidonta truncata

having groove-like sculpture. There are three cardinal teeth, one in the right and two in the left valve; the lateral teeth are strong.

Locality. Goat island.

Genus UNIO Retzius. 1788

The shell is inequilateral, elongated, rounded in front and pointed behind, with a slight posterior ridge; beaks full, slightly sculptured; surface smooth.

**Unio gibbosus** Barnes 1823 (Fig. 188). Unio nasuta Lamarck (1819. *Animaux sans vertèbres,* 6:75). Unio gibbosus Barnes (1823. *Am. jour. sci.* 6:262)

Shell solid, ovate and elongated; rounded at the anterior end, angulated slightly at the posterior; dorsal margin straight or nearly so; ventral margin oval; muscle impressions deep and well defined;

Fig. 188 Unio gibbosus

teeth large and strong, the left valve having two cardinals, and two laterals; growth lines coarse; pallial line deep and clear; beaks turncated and slightly sculptured, the sculpture consisting of two or three strong ridges running parallel to the growth lines.

Found in nearly all the localities. This species seems to have been the most common of the Unios.

Genus QUADRULA Rafinesque. 1820

Shell thick, heavy and solid; teeth large and strong.

**Quadrula solida** (Lea) Simpson 1900 (Fig. 189). Unio solidus Lea (1838. *Phil. soc. Trans.* 6:13). Quadrula solida Simpson (1900. *U. S. nat. mus. Proc.* 22:789)

Shell oval, solid and thick, surface marked by concentric growth lines; anterior end rounded; posterior end slightly angulated; dorsal

margin oval; ventral margin sloping inward toward the posterior end; muscle impressions deep, anterior adductor muscle scar-pitted; cardinal teeth large and heavy; laterals strong and straight or nearly so, with deep, wide impressions; beaks large and prominent, showing no sculpture.

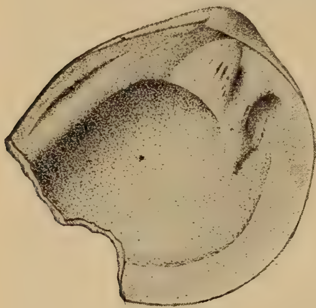

Fig. 189 Quadrula solida

Locality. From excavations in Prospect park.

**Quadrula coccinea** (Conrad) Simpson 1900 (Fig. 190). Unio coccineus Conrad (1836. *Monograph,* 3:29) Quadrula coccinea Simpson (1900. *U. S. nat. mus. Proc.* 22:788)

Shell quadrate, oval, thick and heavy, somewhat compressed posteriorly; anterior end oval; posterior end produced, angulated; dorsal margin oval; ventral margin rounded anteriorly, produced and pointed at the posterior end; the anterior adductor muscle impression deep, pitted above, triangular, showing radiating lines; posterior adductor impression somewhat indistinct; cardinal teeth large and strong, double in each valve; laterals strong, blade-like, two in the left valve and one in the right; beaks large, produced, showing no sculpture, and widely incurving; dorsal margin excavated at the umbones; surface marked by heavy, regular growth lines, resembling concentric waves.

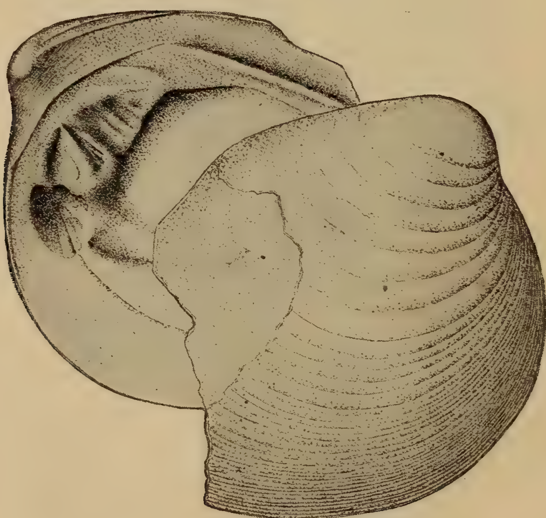

Fig. 190 Quadrula coccinea

Locality. Found in nearly all the deposits.

# APPENDIX

## Partial bibliography of the geology of Niagara and the Great lakes

**Ashburner, C. A.** The geology of Buffalo as related to natural gas in New York state. Am. inst. min. eng. Trans. 16:1-54. 1888.

**Bakewell, R.** Observations on the falls of Niagara, with references to the changes which have taken place, and are now in progress. Am. jour. sci. 2d ser. 23:85-95. 1857.

——— Observations on the whirlpool and the rapids below the falls of Niagara; designed by illustrations to account for the origin of both. Am. jour. sci. 2d ser. 4:25-36. 1847.

**Ballou, H. W.** Niagara river. Scientific Am. sup. 13:5045-46. 1882.

**Bishop, I. P.** Salt wells of western New York. 5th an. rep't N. Y. state geologist. p. 12-47. 1886.

——— Structural and economic geology of Erie county [N. Y.]. 15th an. rep't N. Y. state geologist. 1:17-18, 305-92, pl. 1-16, fig. 1-6; 49th an. rep't N. Y. state mus. 2:305-92, pl. 1-16, fig. 1-6. 1898.

**Chalmers, Robert.** Pleistocene marine shore lines on the south side of the St Lawrence valley. Am. jour. sci. 4th ser. 1:302-8. 1896.

**Clarke, J. M.** The Oriskany Fauna of Becraft mountain. N. Y. state mus. Mem. 3. p. 95-103.

**Claypole, E. W.** Pre-glacial formations of the beds of the great American lakes. Can. nat. n. s. 9:213-27. 1881.

——— Evidence from the drift of Ohio, Indiana and Illinois in support of the pre-glacial origin of the basins of Lakes Erie and Ontario. Am. ass'n adv. sci. Proc. 30:147-59. 1882.

——— Eccentricity theory of glacial cold versus the fact. Edinburgh geol. soc. Trans. 5:534-48. 1885.

——— The old gorge at Niagara. Science. 8:236. 1886.

——— Buffalo and Chicago or "What might have been." Am. nat. 20:856-62; 1886. Am. ass'n adv. sci. Proc. 35:224. 1887.

——— On the pre-glacial geography of the region of the great lakes. Can. nat. n. s. 8:187-206. 1887.

——— Falls of rock at Niagara. Nature. 39:367. 1889.

**Coleman, Arthur P.** Glacial and interglacial deposits at Toronto (Canada). Brit. ass'n adv. sci. Rep't 1897. p. 650, 651.

——— Lake Iroquois and its predecessors at Toronto (Canada). Abstracts, Geol. soc. Am. Bul. 10:165-76; Am. geol. 33:103-4; Science. n. s. 9:143, 144.

**Davis, William Morris.** Was Lake Iroquois an arm of the sea? Am. geol. 7:139-41. 1891.

——— The ancient outlet of Lake Michigan. Pop. sci. mo. 46:217-29. 1895.

——— [Review of "Origin of the gorges of the whirlpool rapids at Niagara" by F. B. Taylor]. Science. n. s. 7:627. 1898.

——— Ancient coastal plain of western New York. Textbook of physical geography. p. 137, 138, fig. 86. 1899.

**Dawson, George M.** Inter-glacial climatic conditions. Am. geol. 16:65, 66. 1895.

**Desor, E.** Note sur l'existence de coquilles marines des mers actuelles dans le bassin du Lac Ontario (Canada) jusqu' a l'altitude de 310 pieds. Soc. geol. France. Bul. 2d ser. 8:420-23. 1851.

——— On the ridge road from Rochester to Lewiston, and on other similar terraces. Bost. soc. nat. hist. Proc. 3:358-59. 1851.

——— Ueber Niagara falls. Deutsche Geologische Gesellschaft, Zeitschrift. 5:643-44. 1853.

——— The falls of Niagara. Pottsville sci. ass'n. Bul. p. 5-10. 1855.

**Fairchild, H. L.** Glacial lakes of western New York. Geol. soc. Am. Bul. 6:353-74, pl. 18-23. 1895.

——— Lake Newberry the probable successor of Lake Warren. Abstract, Geol. soc. Am. Bul. 6:462-66. 1895.

——— Glacial Genesee lakes. Geol. soc. Am. Bul. 7:423-52, pl. 19-21. 1896.

——— Glacial geology of western New York. Geol. mag. Dec. 4, 4:529-37; Brit. ass'n adv. sci. Rep't 1897. p. 664.

——— Lake Warren shore lines in western New York and the Geneva beach. Geol. soc. Am. Bul. 8:269-84, pl. 30. 1897.

——— Glacial lakes Newberry, Warren and Dana in central New York. Am. jour. sci. 4th ser. 7:249-63, fig. 1, pl. 6. 1899.

**Featherstonhaugh, G. W.** On the ancient drainage of North America and the origin of the cataract of Niagara. Am. jour. of geol. and nat. sci. 1:13-21. 1831.

**Fleming, Mary A.** Pot holes of Foster's flats (now called Niagara glen) on the Niagara river. Abstract, Am. ass'n adv. sci. Proc. 48:226, 227; Science. n. s. 10:489. 1899.

**Foerste, Aug. F.** On Clinton conglomerates and wave marks in Ohio and Kentucky. With a résumé of our knowledge of similar occurrences in other Silurian strata of these states, and their evidence upon probable land conditions. Jour. of geol. 3:50-60, 169-97. 1895.

——— Account of the Middle Silurian rocks of Ohio and Indiana, including the Niagara and Ohio Clinton, and the bed at the top of the Lower Silurian strata, formerly considered the Medina. Cin. soc. nat. hist. Jour. 18:161-99. 1896.

——— Report on the Niagara limestone quarries of Decatur, Franklin and Fayette counties, with remarks on the geology of the Middle and Upper Silurian of these and neighboring counties of Indiana. Ind. dep't geol. and nat. res. 22d an. rep't. p. 195-255, pl. 14-18. 1898.

**Foot, Lyman.** Notices of geology and mineralogy (of Niagara falls region). Am. jour. sci. 4:35-37. 1822.

**Gebhard, John.** Observations on the geological features of the south side of the Ontario valley. Albany institute. Trans. 1:55-59. 1830; Am. jour. sci. 11:213-18. 1826.

**Geer, Gerard de.** On Pleistocene changes of level in eastern North America. Am. geol. 11:22-44; Bost. soc. nat. hist. Proc. 25:454-77. 1893.

**Gibbes, L. R.** Remarks on Niagara falls. Am. ass'n adv. sci. Proc. v. 10, pt 2, p. 69-78. 1857.

——— On some points which have been overlooked on the past and present condition of Niagara falls. Elliott soc. nat. hist. Proc. (S. C.) 1:91-100. 1859.

**Gilbert, G. K.** Old shore lines of Lake Ontario. Science. 6:222. 1885.

——— On a prehistoric hearth under the Quaternary deposits in western New York. Sci. Am. sup. 23:9221-22. 1887.

——— The place of Niagara falls in geological history. Am. ass'n adv. sci. Proc. 35:222-24. 1887.

——— Old shore lines in the Ontario basin. Can. inst. Proc. 3d ser. 6:2-4. 1888.

——— Changes of level of the Great lakes. Forum. 5:417-28. 1888.

——— History of Niagara river. 6th an. rep't. N. Y. state com. res. at Niagara. p. 61-84, 7 plates. 1890.

——— Discussion of the papers "Relationship of the glacial lakes Warren, Algonquin, Iroquois and Hudson-Champlain," and the two papers by J. W. Spencer, "The Iroquois shore north of the Adirondacks" and "Channels over divides not evidence per se of glacial lakes". Geol. soc. Am. Bul. 3:492-94. 1892.

———Itinerary, Chicago to Niagara falls. Int. cong. geol., Compte Rendu, 5th session. p. 453-58. 1894.

——— Old tracks of Erian drainage in western New York. Abstract. Geol. soc. Am. Bul. 8:285-86. 1897.

——— Recent earth movements in the Great lakes region. U. S. geol. sur. 18th an. rep't. pt 2, p. 601-47, pl. 105, fig. 93-101. 1898; Nat. geog. mag. 8:233-47, fig. 1-7. 1897; Abstract, Nature. 57:211-13, fig. 1. 1897; Am. geol. 23:126, 127; Am. jour. sci. 4th ser. 7:239-41; 15th an. rep't com. state res. at Niagara. p. 69-138, fig. 93-101. 1899.

——— Ripple marks and cross bedding. Geol. soc. Am. Bul. 10:135, 140, pl. 13, fig. 5; Abstract, Am. geol. 23:102; Science. n. s. 9:138. 1899.

——— Glacial sculpture in western New York. Geol. soc. Am. Bul. 10:121-30; Abstract, Am. geol. 23:103; Science. n. s. 9:143. 1899.

——— Niagara falls and their history. Nat. geog. Monog. v. 1, no. 7. 1895.

**Gordon, C. H.** [Review of "Correlation of Erie-Huron beaches with outlets and moraines in southeastern Michigan" by F. B. Taylor]. Jour. geol. 5:313-17. 1897.

**Grabau, A. W.** Siluro-Devonic contact in Erie county, New York. Geol. soc. Am. Bul. 11:347-76, pl. 21-22. 1900.

**Grant, C. C.** Geological notes. Hamilton ass'n. Jour. and proc. no. 12, p. 140-45. 1896.

**Grote, A. R. & Pitt, W. H.** New specimens from the Waterlime group at Buffalo, N. Y. Am. ass'n adv. sci. Proc. 26:300-2. 1878.

**Gunning, W. D.** Past and future of Niagara. Pop. sci. mo. 1:564-73. 1872.

**Hall, James.** Niagara falls, their physical changes and the geology and topography of the surrounding country. Bost. jour. nat hist. 4:106-34. 1834.

——— Geology of New York. Pt 4, Fourth geological district. Albany. 1843.

——— Glaciated surfaces of cherty limestone from near Niagara. Am. jour. sci. 45:332. 1843.

——— On the geology of the region of Niagara falls. Bost. soc. nat. hist. Proc. 1:52. 1844.

——— Paleontology of New York, v. 2. Organic remains of lower middle division of the New York system. Albany. 1852.

——— Note (on recession of Niagara falls). Am. ass'n adv. sci. Proc. v. 10, pt 2, p. 76-79. 1857.

——— (Description of Siluric formations of New York). Fossils of the Waterlime group. Pal. N. Y. 3:20-32, 282-424. 1859.

———On the relations of the middle and upper Silurian (Clinton, Niagara and Helderberg) rocks of the United States. Geol. mag. 9:509-13. 1872.

——— On the relations of the Niagara and Lower Helderberg formations, and their geographical distribution in the United States and Canada. Am. ass'n adv. sci. Proc. v. 22, pt 2, p. 321-35. 1874.

——— Descriptions of fossil corals from the Niagara and Upper Helderberg groups. 35th an. rep't N. Y. state mus. nat. hist. p. 407-64, pl. 23-30. 1884.

——— Niagara falls, its past, present and prospective condition. Rep't 4th geol. dist. N. Y. p. 383-404. 1842; 8th an. rep't com. state res. at Niagara. p. 67-89. 1892.

**Hallett, P.** Notes on Niagara. British ass'n. Rep't of 54th meeting, p. 744-45. 1885.

**Hitchcock, C. H.** The story of Niagara. Am. antiquarian. 23:1-24, 12 fig. Jan. 1901.

**Holley, George W.** Niagara, its history, geology, incidents and poetry, New York. 1872.

——— The proximate future of Niagara, in review of Professor Tyndall's lecture thereon. Am. ass'n adv. sci. Proc. v. 22, pt 2, p. 147-55. 1874; Abstract, Can. nat. n. s. 7:164-65. 1875.

**Hovey, Horace C.** Niagara river, gorge and falls. Sci. Am. sup. v. 22, no. 558, p. 897. 1886.

**Hyatt, Alpheus.** Rock ruins (Niagara falls). Am. nat. 2:77-85. 1869.

**Leverett, Frank.** On the correlation of New York moraines with raised beaches of Lake Erie. Am. jour. sci. 3d ser. 1:1-20. 1895.

——— Pre-glacial valleys of the Mississippi and tributaries. Jour. of geol. 3:740-63. 1895.

——— The Pleistocene features and deposits of the Chicago area. Chicago acad. sci. Bul. no. 2, 86p., pl. 1-4, fig. 1-8. 1897.

——— Correlation of moraines with beaches on the border of Lake Erie. Am. geol. 21:195-99. 1898.

**Lesley, Joseph P.** On the glacial erosion and outlets of the Great lakes. Am. phil. soc. Proc. 20:95-101. 1883.

**Lyell, Charles.** Niagara falls. Travels in North America, v. 1, ch. 2, p. 22-43. 1845.

**Marcou, Jules.** Le Niagara quinze ans apres. Soc. géol. France. Bul. 2d ser. 22:290-300, 529-30. 1865.

**Maw, George.** Geological history of the North American lake region. Geol. mag. n. s. 5:455-56. 1878.

**Merrill, F. J. H.** A guide to the study of the collections of the New York state museum. N. Y. state mus. Bul. no. 19, p. 107-262. 1898.

**Mudge, E. H.** Central Michigan and the post-glacial submergence. Am. jour. sci. 3d ser. 1:442-45. 1895.

**Newberry, John S.** Notes on the surface geology of the basins of the Great lakes. Bost. soc. nat. hist. Proc. 9:42-46. 1865.

——— On the surface geology of the basins of the Great lakes and the valley of the Mississippi. N. Y. lyceum nat. hist. Annals. 9:213-34. 1870; Am. nat. 4:193-218. 1871.

——— On the structures and origin of the Great lakes. N. Y. lyceum nat. hist. Proc. 2d ser. p. 136-38. 1874.

——— On the origin and drainage of the basins of the Great lakes. Am. phil. soc. Proc. 20:91-95.

——— History of the great American lakes. Abstract. Sci. Am. sup. 28:11,505-6; Eng. and min. jour. 48:201-2. 1889.

**Nicholson, H. Alleyne.** On the Guelph limestones of North America and their organic remains. Geol. mag. n. s. 2:343-48. 1875.

**Pohlman, Julius.** Cement rock and gypsum deposits in Buffalo. Am. inst. min. eng. Trans. Buffalo meeting 1888.

——— Life history of Niagara. Am. inst. min. eng. Trans. Buffalo meeting p. 1-17.

——— Thickness of the Onondaga salt group at Buffalo, N. Y. Buffalo soc. nat. sci. Bul. v. 5, no. 1, p. 97, 98. 1886.

——— Niagara gorge. Am. ass'n adv. sci. Proc. 35:221. 1887.

——— Life history of the Niagara river. Am. ass'n adv. sci. Proc. 32:202. 1884.

——— Fossils from the Waterlime group at Buffalo, N. Y. Buffalo soc. nat. sci. Bul. v. 5, no. 1, p. 97, 98. 1886.

——— On certain fossils of the Waterlime group near Buffalo. Buffalo soc. nat. sci. Bul. v. 4, no. 1, p. 17-22. 1882.

——— Additional notes on the fauna of the Waterlime group near Buffalo. Buffalo soc. nat. sci. Bul. v. 4, no. 2, p. 41-46. 1882.

**Quereau, Edmund Chase.** Topography and history of Jamesville lake, New York. Geol. soc. Am. Bul. 9:173-82, pl. 12-14. 1898.

**Ringueberg, E. N. S.** The crinoidea of the lower Niagara limestone at Lockport, N. Y. with new species. N. Y. acad. sci. An. 5:301-6, pl. 3. 1891.

**Ringueberg, E. N. S.** Evolution of forms from the Clinton to the Niagara group. Am. nat. 16:711-15, fig. a-e. 1887.

——— Niagara shales of western New York; a study of the origin of their subdivisions and their faunae. Am. geol. 1:264-72. 1888.

——— New genera and species of fossils from the Niagara shales. Buffalo soc. nat. sci. Bul. v. 5, no. 2, p. 5-21, pl. 1, 2. 1886.

**Rogers, Henry D.** On the falls of Niagara, and the reasonings of some authors respecting them. Am. jour. sci. 27:326-35. 1835.

**Russell, Israel Cook.** Geography of the Laurentian basin. Am. geog. soc. Bul. 30:226-54, 6 fig. 1898.

**Schmidt, Friedrich.** Eurypterus beds of the Oesel as compared with those of North America. Geol. soc. Am. Bul. 3:59, 60. 1892.

**Scovell, J. T.** An old channel of the Niagara river. Am. ass'n adv. sci. Proc. 39:245. 1891.

**Shaler, N. S.** Geology of Niagara. The Niagara book. Buffalo N. Y.

**Spencer, J. W.** Short study of the features of the region of the lower Great lakes during the Great river age; or, Notes on the origin of the Great lakes of North America. Am. ass'n adv. sci. Proc. 30:131-46. 1882.

——— Discovery of the pre-glacial outlet of the basin of Lake Erie into that of Lake Ontario, with notes on the origin of our lower Great lakes. Am. phil. soc. Proc. 24:409-16, pl. 6, 7. 1882; 2d geol. sur. Pa. Rep't Q 4, p. 357-404.

——— Traces of beaches about Lake Ontario. Am. jour. sci. 24:409-16, pl. 6, 7. 1882.

——— Paleozoic and surface geology of the region about the western end of Lake Ontario. Can. nat. n. s. 10:129-71, 213-36, 265-312. 1883.

——— Terraces and beaches about Lake Ontario. Am. ass'n adv. sci. Proc. 31:359-63. 1883.

——— Age of the Niagara river. Am. nat. 21:269-70. 1887.

——— The Iroquois beach, a chapter in the history of Lake Ontario. Abstract, Science. 11:49. 1888.

——— The St Lawrence basin and the Great lakes. Abstract, Can. rec. of sci. 3:232-35. 1888; Science. 12:99-100. 1888; Sci. Am. sup. 26:10,671-72. 1888; Am. geol. 2:346-48. 1888; Am. ass'n adv. sci. Proc. 37:197-99. 1889; Am. nat. 23:491-94. 1889.

——— Notes on the origin of the Great lakes of North America. Am. ass'n adv. sci. Proc. 37:197, 198. 1889.

——— The Iroquois beach; a chapter in the geological history of Lake Ontario. Roy. soc. Can. Trans. v. 7, §4, p. 121-24. 1890; Abstract, Am. nat. 24:957; Am. geol. 6:311-12. 1890.

——— The deformation of the Iroquois beach and birth of Lake Ontario. Am. jour. sci. 40:443-52. 1890.

——— The northwestern extension of the Iroquois beach in New York. Am. geol. 6:294, 295. 1890.

——— Deformation of the Algonquin beach, and birth of Lake Huron. Am. jour. sci. 3d ser. 41:12-21. 1891.

**Spencer, J. W.** High-level shores in the region of the Great lakes and their deformation. Am. jour. sci. 41:201-12. 1891.

——— Prof. W. M. Davis on the Iroquois beach. Am. geol. 7:68, 266. 1891.

——— Origin of the basins of the Great lakes of America. Am. geol. 7:86-97. 1891.

——— Channels over divides not evidence per se of glacial lakes. Geol. soc. Am. Bul. 3:491-92; Abstract, Am. geol. 11:58. 1892.

——— Review of the history of the Great lakes. Am. geol. 14:289-301, pl. 8. 1894.

——— Drainage of the Great lakes in the Mississippi by way of Chicago. Abstract, Am. nat. 28:884. 1894.

——— Deformation of the Lundy Beach and birth of Lake Erie. Am. jour. sci. 3d ser. 47:207-12. 1894.

——— Niagara falls as a chronometer of geological time. Abstract, Roy. soc. London. Proc. 1:145-48. 1894.

——— Age of Niagara falls. Am. geol. 14:135, 136. 1894.

——— Duration of Niagara falls. Am. jour. sci. 3d ser. 48:455-72: Abstract, Am. geol. 14:204 (7l.); Abstract, Am. nat. 28:859-62. 1894.

——— [Lake Newberry as the probable successor of Lake Warren]. Geol. soc. Am. Bul. 6:466. 1895.

——— Duration of Niagara falls. Abstract, Am. ass'n adv. sci. 43:244-46. 1895.

——— Geological survey of the Great lakes. Am. ass'n adv. sci. Proc. 43:237-43. 1895.

——— Niagara as a time piece. Pop. sci. mo. 49:1-19, fig. 1-17. 1896.

——— How the Great lakes were built. Pop. sci. mo. 49:157-72, fig. 1-15. 1896.

——— On the continental elevation of the glacial epoch. Brit. ass'n adv. sci. Rep't 1897. p. 661, 662. 1898.

——— On Mr Frank Leverett's "Correlation of moraines with beaches on the border of Lake Erie." Am. geol. 21:393-96, fig. 1. 1898.

——— Another episode in the history of Niagara river. Abstract, Am. ass'n adv. sci. Proc. 47:299; Science. n. s. 8:501, 502; Am. geol. 22:259-60; Am. jour. sci. 4th ser. 6:439-50, 2 fig. 1898.

——— Niagara as a time piece. Can. inst. Proc. n. s. 1:101-3. 1898.

**Stose, George W.** A specimen of Ceratiocaris acuminata Hall from the Waterlime of Buffalo, N. Y. Bost. soc. nat. hist. Proc. 26:369-71. 1894.

**Tarr, Ralph S.** Physical geography of New York state. pt 7. The Great lakes and Niagara. Am. geog. soc. Bul. 31:101-17 (4 fig.), 217-35 (10 fig.), 315-43 (21 fig.) 1899.

**Taylor, F. B.** The highest old shore-line on Mackinac island. Am. jour. sci. 3d ser. 43:210-18; Abstract, Am. ass'n adv. sci. Proc. 40:260-61. 1892.

**Taylor, F. B.** The limit of post-Glacial submergence in the highlands east of Georgian Bay [Ontario]. Am. geol. 14:273-89, with map. 1894.

——— The ancient strait at Nipissing [Ontario]. Geol. soc. Am. Bul. 5:620-26, pl. 20; Abstract, Am. geol. 13:220-21. 1894.

——— A reconnaissance of the abandoned shore lines of Green bay [Michigan and Wisconsin]. Am. geol. 13:316-27, with a map. 1894.

——— A reconnaissance of the abandoned shore lines of the south coast of Lake Superior. Am. geol. 13:365-83, with map. 1894.

——— The Nippissing beach on the north Superior shore. Am. geol. 15:304-14. 1895.

——— Niagara and the Great lakes. Am. jour. sci. 3d ser. 49:249-70. 1895.

——— The Munuscong islands [Michigan]. Am. geol. 15:24-33. 1895.

——— The second Lake Algonquin. Am. geol. 15:100-20 and 162-79. 1895.

——— Changes of level in the region of the Great lakes in recent geological time. [Letter to J. D. Dana] Am. jour. sci. 3d ser. 49:69-71. 1895.

——— [On the use of the term "Erigan"]. Am. geol. 15:394-95. 1895.

——— Preliminary notes on studies of the Great lakes made in 1895. Am. geol. 17:253-57. 1896.

——— The Algonquin and Nipissing beaches. Am. geol. 17:397-400. 1896.

——— Notes on the Quaternary geology of the Mattawa and Ottawa valleys [Ontario]. Am. geol. 18:108-20. 1896.

——— Correlation of Erie Huron beaches with outlets and moraines in southeastern Michigan. Geol. soc. Am. Bul. 8:31-58, pl. 2. 1897.

——— Scoured boulders of the Mattawa valley [Ontario]. Am. jour. sci. 4th ser. 3:208-18. 1897.

——— The Nipissing-Mattawa river the outlet of the Nipissing great lakes. Am. geol. 20:65-66. 1897.

——— Short history of the Great lakes. Studies in Indiana geography, ed. by C. R. Dryer. 1:90-110, fig. 1-4. 1897.

——— The Champlain submergence and uplift, and their relation to the Great lakes and Niagara falls. Brit. ass'n adv. sci. Rep't 1897. p. 652-53. 1898.

——— Origin of the gorge of the whirlpool rapids at Niagara. Geol. soc. Am. Bul. 9:59-84, fig. 1, 2. 1898.

——— The great ice dams of Lakes Maumee, Whittlesey and Warren. Am. geol. 24:6-38, pl. 2, 3. 1899.

**Tyndall, John.** Some observations on Niagara. Pop. sci. mo. 3:210-26. 1873.

**Upham, Warren.** Relationship of the Glacial lakes Warren, Algonquin, Iroquois and Hudson-Champlain. Abstract, Geol. soc. Am. Bul. 3:484-87; Abstract, Am. geol. 11:59. 1892.

——— The Champlain submergence. Abstract, Geol. soc. Am. Bul. 3:508-11; Abstract, Am. geol. 11:119. 1892.

**Upham, Warren.** The fjords and Great lakes basins of North America considered as evidence of pre-glacial continental elevation and of depression during the glacial period. Geol. soc. Am. Bul. 1:563-67. 1890.

——— Altitude as the cause of the glacial period. Science. 22:75, 76. 1893.

——— Estimates of geologic time. Am. jour. sci. 3d ser. 45:209-20; Sci. Am. sup. 35:14, 403-5. 1893.

——— Epeirogenic movements associated with glaciation. Am. jour. sci. 3d ser. 46:114-21. 1893.

——— Wave-like progress of an epeirogenic uplift. Jour. of geol. 2:383-95. 1894.

——— The Niagara gorge as a measure of the post-glacial period. Am. geol. 14:62-64. 1894.

——— Stages of recession of the North American ice sheet, shown by glacial lakes. Am. geol. 15:396-99. 1895.

——— Departure of the ice sheet from the Laurentian lakes. Abstract, Geol. soc. am. Bul. 6:21-27. 1895.

——— Late glacial or Champlain subsidence and reelevation of the St Lawrence river basin. Am. jour. sci. 3d ser. 49:1-18, with map. 1895; Minn. geol. and nat. hist. sur. 23d an. rep't, p. 156-93. 1895.

——— Beaches of Lakes Warren and Algonquin. Am. geol. 17:400-2. 1896.

——— Origin and age of the Laurentian lakes and of Niagara falls. Am. geol. 18:169-77, fig. 1. 1896.

——— Niagara gorge and Saint Davids channel. Geol. soc. Am. Bul. 9:101-10. 1898.

**Walker, A. E.** Hamilton sponges [Ontario]. Hamilton ass'n. Jour. and proc. no. 11, p. 85-87. 1895.

**Weller, Stuart.** The Silurian fauna interpreted on the epicontinental basis. Jour. geol. 6:692-703, 2 fig. 1898.

——— Paleontology of the Niagaran limestone in the Chicago area. The Crinoidea. Chicago acad. of sci. The natural history survey. . . Bul. 4, pt 1. 1900.

**Westgate, Lewis G.** Geographic development of the eastern part of the Mississippi drainage system. Am. geol. 11:245-60; Abstract, Jour. of geol. 1:420, 421. 1893.

**Winchell, Alexander N.** Age of the Great lakes of North America. Am. geol. 19:336-39. 1897.

**Woodward, R. S.** On the rate of recession of the Niagara falls, as shown by the results of a recent survey. Am. ass'n adv. sci. Proc. 35:222. 1886.

**Worthen, A. H.** Remarks on the relative age of the Niagara and so-called Lower Helderberg groups. Am. ass'n adv. sci. Proc. 19:172-75. 1870.

**Wright, G. F.** Niagara river and the glacial period. Am. jour. sci. 28:33-35. 1884.

——— The ice age in North America. Appleton. 1889.

**Wright, G. F.** The supposed post-glacial outlet of the Great lakes through Lake Nipissing and the Mattawa river. Geol. soc. Am. Bul. 4:423-25. 1893.

——— Age of Niagara falls as indicated by the erosion at the mouth of the gorge. Abstract, Am. ass'n adv. sci. Proc. 47:299-300; Abstract, Science. n. s. 8:502; Abstract, Am. geol. 22:260, 261. 1898.

——— New method of estimating the age of Niagara falls. Pop. sci. mo. 55:145-54, 6 fig. 1899.

——— Lateral erosion at the mouth of the Niagara gorge. Abstract, Science. n. s. 10:488. 1899.

## Glossary

**aberrant**—differing from the type
acanthopores—hollow spines occurring between the apertures, on the frond of a bryozoan
acinus—a berry
adductor muscles—closing muscles in bivalve shells
agglutinate—firmly united
air-chambers—chambers below the living chamber in the shells of cephalopods
alar—pertaining to wings; the lateral primary septa of the tetracoralla
alate—having wing-like expansions
ambulacral areas—perforated areas in the test of an echinoderm, through which the tubed feet project
anastomosing—uniting to form a net work
angulated—with angles or corners
ankylosed—firmly united; grown together
annulations—rings, or ring-like segments
annulus—a ring; a segment of the thorax of a trilobite
antennae—paired articulated appendages of head of arthropod—trilobite
anterior—front
aperture—opening of shells, cells, etc.
apex—terminal or first-formed portion of gastropod shells
apophysis—a calcareous process (in interior of shells, etc.)
appressed—pressed closely against
arcuate—arched; bent like a bow
articulated—joined by interlocking processes, or by teeth and sockets
asperate—rough
attenuated—tapering; or thinning
auricle—ear, or anterior projection of the hinge of many pelecypods
auriculate—eared
aviculoid—resembling Avicula, winged
axial canal—central canal of crinoid stem
axial furrows—furrows or depressions delimiting the axis in trilobites
axis—central longitudinal division of the body of a trilobite
azygous—unpaired; the azygous side of the calyx of a crinoid has plates differing from those of the regular sides

**basals**—lowest cycle or cycles (in forms with dicyclic base) of plates in the crinoidea
beak—area of the apex or initial point of a shell
biconvex—both valves convex, as in most brachiopods
bifid—split in two
bifoliate—two-leaved
bifurcating—dividing in two, forking

biserial—with double series or rows
brachial—pertaining to the brachia or arms of brachiopods or crinoids; one of the arm plates of crinoids
brachidium—calcareous support of the arms in brachiopods
branchiae—gills
bryozoum—whole compound colony of the bryozoa
bulbiform—bulb-shaped
byssal notch—notch or opening for the emission of the byssus (supporting-threads spun by the foot) in the pelecypoda

**calicinal**—pertaining to the calyx or cup
callosity—hardened spot or area
callus—thickened part of the inner lip of gastropods, which usually covers portions of the preceding volutions
calyx—1) cup of corals, limited below by the septa; 2) body, exclusive of the arms, of crinoids, cystoids and blastoids
camerate—chambered; an order of crinoidea
camerae—air-chambers of a cephalopod shell
canaliculate—channeled; having a canal
cancellated—marked by lines crossing each other; lattice-like
carapace—hard shell or shield of crustacea
cardinal—pertaining to the area of the beak in brachiopods and pelecypods
cardinal process—process from under the beak of the brachial valve of brachiopods, to which the diductor (opening) muscles are attached
cardinal quadrants—two quadrants of a Tetracorallum which bound the main, or cardinal, septum
cardinal septum—first or main of the four primary septa of a Tetracorallum; the cardinal septum has the pinnate arrangement of the secondary septa on both sides
cardinal teeth—teeth under the beak in the pelecypods; teeth in the pedicle valve of the brachiopods
carina—projecting ridge running down the center of the branches in some fenestelloid and other bryozoa; the projecting ridges on the septa of Heliophyllum and other corals
carinated—having a ridge or keel
cartilage—compressible, elastic substance between the hinge-margins of the valves of pelecypods. The cartilage is the internal, as the ligament is the external medium for opening the valves
cast—the impression taken from a mold
caudal—pertaining to the tail
celluliferous—cell bearing (bryozoa commonly have a celluliferous and a non-celluliferous side)
cephalic limb—anterior border of the cephalon of a trilobite
cephalon—head-shield of trilobites
cephalothorax—combined head and thorax of crustacea
cercopods—lateral tail spines in the ceratiocarida

cespitose—matted, tangled or growing in low tufts
cheeks—lateral portions of the cephalon, divided into fixed and free cheeks, of a trilobite
chelae—pincer-like claw terminating some of the legs of crustacea
chilidium—covering for the chilyrium
chilyrium—triangular opening under the beak of the brachial valve in those brachiopods in which that valve is furnished with a hinge area
chitinous—composed of chitin, the substance forming the horny wings or elytra of beetles, and the carapaces of crustacea
cicatrix—a scar
cincture—depression anterior to the beak in the shell of some pelecypods
cirri—root-like appendages to the stem of crinoids
clastic—consisting of fragments, i. e. rocks made of fragments of older rocks
clavate—club-shaped
clavicle—heavy internal ridge running downward from the beak in some pelecypods
columella—central or axillary rod
compound corallum—made up of corallites, either separate or closely joined by their walls (ex. Favosites)
composite corallum—compound corallum with coenenchyma or extrathecal calcareous tissue connecting the corallites (ex. Galaxia and many other recent forms)
concavo-convex—shells of brachiopods are normally concavo-convex, when the brachial valve is concave, and the pedicle valve convex; reversed or resupinate, when the reverse condition obtains
confluent—blended so that the line of demarcation is not visible
coniferae—order of arborescent plants to which the pines, firs, etc. belong
consequent stream—type of stream which flows down the original constructional slope of the land
corallites—individual tubes of a compound corallum
corallum—calcareous skeleton of a single, or of a colonial, coral stock
corneous—horny
coronal—crown-like
costae—extrathecal extensions of the septa of the corals
costals—first brachial or arm-plates of the crinoids lying between the radials and the first bifurcation of the arms
counter quadrants—quadrants bounding the counter septum of a Tetracorallum
counter septum—front primary septum of the Tetracoralla, opposite the cardinal septum; the secondary septa are parallel to it
crenulated—notched to produce series of teeth
crura—apophyses to which the brachidium of the brachiopods is attached
cuesta—topographic relief element, resulting from the normal dissection of a coastal plain composed of alternating harder and softer strata (see p. 40)

cuneate—wedge-shaped
cuneiform—wedge-shaped
cyathophylloid—in form like Cyathophyllum; one of the Tetracoralla
cyst—a closed cavity
cystoid—most primitive class of Pelmatozoa or stemmed echinoderms

**delthyrium**—triangular fissure under the beak of the pedicle valve of the brachiopoda
deltidium—single covering plate of the delthyrium (also called pedicle plate)
deltidial plates—two plates which close the delthyrium in the higher brachiopoda (Telotremata)
dendroid—branching after the manner of a tree
dental plates—internal plates below the teeth in pedicle valve of the brachiopoda
denticles—small teeth, or tooth-like ridges
denticulate—toothed
denticulation—set of denticles or small teeth
depressed—on a level with, or below the general surface
dextral (right handed)—the normal method of coiling in the gastropoda
diaphragm—transverse partitioning plate
dicyclic—with two cycles of basals; applied to crinoids
diductor muscles—opening muscles of the brachiopoda
discinoid—resembling Discina
discoid—disk-like
dissepiments—partitions; the intrathecal connecting plates between the septa of the corals; the connecting bars between the branches of a fenestelloid bryozoum
distal—situated away from the center of the body
distichals—second series of arm plates or brachials of crinoids, situated above the axillary costals
divaricators—opening muscles of brachiopoda; also called diductors
dorsal—pertaining to the back
doublure—infolded margin of a trilobite

**ear**—anterior cardinal expansion of the pelecypod shell, usually smaller and more distinctly defined than the posterior expansion or wing
echinate—spinous
endoderm—inner cellular body layer
emarginate—with a notched margin
endoderm—inner cellular body layer
endothecal—within the theca; intrathecal; used for corals
epicontinental—encroaching on the continent
epidermal—pertaining to the skin
epitheca—outer calcareous covering of a corallum or bryozoan
equilateral—with similar sides
equivalve—with similar valves
escharoides—like Eschara (a bryozoan)

escutcheon—depression behind the beak of the pelecypod shell
exfoliate—peeling off
exothecal—outside of the theca of corals
explanate—spread out in a flat surface
extrathecal—outside of the theca of corals
extroverted—turned base to base; applied to spirals of brachiopods

**facetted**—having facets or numerous faces as the eye of an insect, etc.
facial sutures—sutures in the cephalon of trilobites which separate the free from the fixed cheeks
facies—local characteristics
falcate—curved like a scythe or sickle
fasciculate—clustered
fathom—a measure of length equaling 6 feet used chiefly for depths of the sea
fenestrule—open spaces between the branches and dissepiments of a fenestella frond
filament—a fine thread or fiber
fimbriae—a fringe
fixed cheek—that part of the cephalon of a trilobite which lies between the glabella and the facial suture
fission—the act of splitting or cleaving into parts
flabellate—fan-shaped
flange—a projecting rim
flexibilia—an order of crinoids characterized by the loose jointing of the plates of the calyx
fold—the central elevation of the valve, usually the brachial of a brachiopod
foliate—leaf-like; in the form of a thin leaf-like expansion
foramen—an opening or pore; specifically the opening for the pedicle in the pedicle valve of the brachiopoda
fossula—groove in the calyx of a coral, usually due to the abortion of a septum
free cheeks—lateral portions of the cephalon of trilobites separated off by the facial sutures
frond—foliaceous or leaf-like expansion of the skeleton of bryozoa and other organisms
fruticulose—resembling a small shrub
fucoid—a seaweed, particularly of the type similar to the modern Fucus, or rockweed

**galeate**—with a helmet-like covering
gastric—pertaining to the stomach
genal angles—posterior lateral angles of the free cheeks of trilobites
genal spines—posterior prolongations, or spines, of the free cheeks of trilobites
geode—a hollow concretion usually lined with crystals, but also filled completely with foreign mineral matter

geodiferous—containing or abounding in geodes
geodetic—geode-bearing, pertaining to geodes
gibbous—swollen or humped
glabella—central, most prominent portion of the trilobite cephalon, bounded by the fixed cheeks
glomerate—growing in dense heads or clusters, generally of an irregular character
gonopolyp—reproductive polyp of Hydrozoa
granulated—having small and even elevations resembling grains
granulose—bearing or resembling grains or granules

**hexacoralla**—class of corals built on the plan of six
hinge area—flat area bordering the hinge line of many brachiopods
hinge line—line of articulation
hydrocoralline—order of Hydrozoa which build calcareous skeletal structures
hydroid—animal belonging to the class of Hydrozoa
hydrotheca—cup inclosing the nutritive polyp in thecaphore Hydrozoa
hyponome—water tube, or squirting organ, of squids, cuttlefish, and other cephalopods
hypostoma—underlip of the trilobites, usually found detached

**imbricate**—overlapping serially
implantation—planting between, as a new plication suddenly appearing between two older ones
inarticulate—not articulating by teeth and sockets; of brachiopoda
incised—cut into
incrusting—covering as with a crust
inequilateral—having unequal sides
inface—steep face or escarpment of a cuesta, facing toward the old-land
inferior—lower in position
inflated—distended in every direction and hollow within
inflected—bent or turned inward or downward
infrabasals—lower cycle of basal plates in the crinoids with dicyclic base
infundibuliform—funnel-shaped
inosculating—connecting, so as to have intercommunication
interambulacral—between the ambulacra
interapertural—between the apertures
interbrachials—plates in the calyx of a crinoid, lying between the brachials
intercalation—irregular interposition
intercellular—between the cells or meshes
interdistichals—plates in the calyx of a crinoid, lying between the distichals
interradials—plates in the calyx of a crinoid, lying between the radials
interstitial—pertaining to an intervening space; between lines, plications, etc.
intervestibular—between the vestibules or circumscribed areas
interzooecial—between the zooecial tubes in bryozoa, etc.

intrathecal—within the theca; endothecal
introverted—turned apex to apex; applied to the spirals of brachiopods
involute—rolled up, as a Nautilus shell

**joints**—component segments of the stem of a crinoid
jugum—yoke-like connection between the two parts of the brachidium of a brachiopod

**keel**—strong central carina or ridge (Taeniopora)

**lacrymiform**—tear-form; drop shaped—pear shaped, but without the lateral contractions
lamellar—disposed in lamellae or layers
lamellibranch—leaf-gilled, the class of molluska with bivalved shell, to which the oyster and clam belong; pelecypod
lamelliform—having the form of a leaf or lamella
lamellose—made up of lamellae
lamina—a thin plate or scale
lateral gemmation—a budding from the sides, as in some corals
lateral teeth—ridge-like projections on either side of the beak, in the interior of lamellibranch shells
laviformia—primitive order of crinoids
ligament—external structure for opening the valves in the pelecypoda
limb—lateral area or marginal band of the cephalon of trilobites on either side of the glabella, corresponding to a pleuron of the thoracic region
lines of growth—lines marking the periodic increase in size, in shells
linguiform—tongue-shaped
linguloid—tongue-shaped; like Lingula
lip—margins of the aperture of univalve shell
listrium—depressed area surrounding the pedicle opening in the pedicle valve of Orbiculoidea and other discinoid brachiopods
lithic—pertaining to stone
living chamber—the last chamber in the shell of a cephalopod, which is occupied by the animal
lobes—backward bending portions of the suture of cephalopod shells
lophophore—ciliated or tentaculated, oral disk of bryozoa; the oral disk and brachia of brachiopods
lunarium—more or less thickened portion of the posterior wall of the cell in many paleozoic bryozoa, which is lunate or curved to a shorter radius, and usually projects above the plane of the cell aperture
lunule—depression in front of the beak of pelecypod shells

**macerate**—softening and disintegrating by immersion in water
macrocorallites—the larger corallites in a compound corallum
maculae—irregular, usually depressed, areas on the celluliferous face of a bryozoan frond, which are free from cells, or otherwise differentiated
mandibles—first upper or outer pair of jaws of crustacea and insects

mantle—fleshy membrane infolding the soft parts of mollusks and brachiopods and building the shell
medullary rays—the "silver grain" or radiating vertical bands or plates of parenchyma in the stems of exogenous plants
medusa—a jelly fish
membranaceous—pertaining to a membrane
mesial—central
mesogloea—central, non-cellular layer in the body of coelenterates
meso-pores—irregular meshes or cysts on the intercellular spaces of certain bryozoa
mesotheca—median wall separating opposed cells in certain bryozoan fronds
metastonia—underlip of crustacea, composed of small pieces immediately below and behind the mouth
microcorallites—smaller corallites of a compound corallum
mold—any impression of a fossil, in rock matrix, external or internal
moniliform—resembling a necklace or string of beads
monocyclic—of a single cycle
monticuliporoids—corals belonging to the order Monticuliporidae having many points of resemblance with the bryozoa
monticules—elevated areas on the surface of certain coral and bryozoan colonies, commonly carrying larger apertures
mucronate—produced into a long pointed extension
mural pores—pores in the walls of the corallites of the Favositidae
muscle scar—scar in a shell marking the former attachment of a muscle

**nacreous**—pearly; the nacreous layer of shells is the inner smooth pearly layer
nariform—shaped like a nostril
nasute—projecting, nose-like
nettlecell—one of the nematocysts or stinging cells found covering the tentacles and other body parts of most Coelenterata
node—knob; usually considered as ornamental
nodose—bearing nodes or tubercles
nodulose—knotty, or having nodes

**obconical**—inversely conical
oblate—flattened at the poles
obovate—inversely ovate or egg-shaped
obsequent stream—a stream flowing down the inface of a cuesta, or toward the old-land, tributary to the subsequent stream which in turn flows into the consequent
occipital—applied to the posterior part of the cephalon of a trilobite
occipital furrow—transverse groove on the cephalon of trilobites, which separates the last or occipital ring from the rest of the cephalon
occipital ring—posterior division of the glabella of a trilobite cephalon
operculiform—resembling an operculum
operculum—lid or cover

**paddles**—large or last pair of thoracic legs of the eurypterids
pallial line—line on the interior of the shell of mollusks marking the attachment of the mantle
pallial sinus—reentrant angle in the pallial line usually at the posterior end of the shell of pelecypods; it marks the attachment of the siphon muscles
palmars—third series of brachial plates of the Crinoidea, lying above the axillary distichals
palmate—palm-shaped
palpebral lobes—supra-orbital extensions from the fixed cheeks of trilobites
papilla—a small nipple-shaped protuberance
papillose—covered with papillae or fine projections
parabasals—second cycle of basal plates in crinoids
pectinated rhombs—paired pore clusters in the calyx of certain cystoids (Callocystites)
pedicle—fleshy peduncle or stem used for attachment in the brachiopoda
pedicle valve—valve which gives emission to the pedicle in the brachiopoda. Ventral of most authors. Usually the larger valve
pentameroid—five chambered, similar to Pentamerus
pentapetalous—resembling a five-petaled flower
penultimate—next to the last
periderm—outer chitinous covering of Hydrozoa
periostracum—epidermis or outer organic coating of shells
peripheral—pertaining to the circumference
peristome—margin of an aperture, i. e. the mouth of a univalve molluscan shell, the mouth of a bryozoan cell, etc.
peritheca—epithecal covering which surrounds a colony of corallites, i. e. a compound corallum
petaloid—resembling a leaf or petal
pinnate—shaped like a feather
pinnulate—provided with pinnules
pinnules—finest divisions of the arms of crinoids
plano-convex—normally in brachiopods, with the pedicle valve convex and the brachial valve flat
pleura—lateral portions of the thoracic rings of trilobites
plicate—plaited or folded
plications—folds or rib-like plaits of a brachiopod shell
polyp—animal of a simple coelenterate or bryozoan
polypite—individual polyp of a colony
pore-rhombs—pore clusters, arranged in rhombic manner in the calyx of cystoids
poriferous—pore-bearing, corals which like Favosites are furnished with several pores
posterior—situated behind

post-palmars—all the plates, superior to the axillary palmars in the arms of crinoids
prehensile—adapted for seizing
preoral—situated in front of the mouth
produced—drawn out, elongated
proliferous—reproducing buds from the calyx
protoconch—embryonic shell of a cephalous molluscan
proximal—nearest or basal portion
pseudocolumella—false columella in corals, formed by a twisting of the septa
pseudodeltidium—false deltidium (Spirifer), formed by union of the two deltidial plates
pseudosepta—septa-like ridges of Chaetetes, etc., the projecting ends of the lunaria in the cells of certain bryozoa
pseudotheca—false wall or theca in some corals, formed by the expansion of the outer margins of the septa
punctate—dotted, with scattered dots or pits
pustule—small blister-like elevation
pustulose—bearing pustules or projections
pygidium—posterior or tail portion of the carapace of trilobites
pyramidal—having the form of a pyramid
pyriform—pear-shaped
pyriformis—pear-shaped

**quadrangular**—four angled
quadrate—with four equal and parallel sides
quadrifid—cut into four points
quadrilobate—bearing four lobes
quadriplicate—with four folds
quincunx—five objects arranged in a square with one in the middle

**rachis**—central stem of a frond in bryozoa, etc.
radials—main plates of the calyx of a crinoid, resting on the parabasals, and alternating with them
radii—ribs or striations diverging from the beak of a shell
ramose—branching
ramus—branch of a skeletal structure
reniform—kidney form
resilium—internal cartilage or compressible substance in the hinge of pelecypods
reticulated—like a network
retractile—capable of being withdrawn
retral—backward
rhynchonelloid—resembling Rhynchonella
root—expanded basal portion of a crinoid stem, used for fixation
rostrum—a beak or snout
rugosa—an old name for the Tetracoralla

saddles—forward bending portions of the suture in the shells of cephalopods
salient—standing out prominently
scabrous—rough or harsh with little projecting points
scalae—small transverse plates in the genus Unitrypa of the bryozoa
scalariform—stair or ladder-shaped
sclerenchyma—calcareous tissue deposited by the coral polyps
scorpioid—scorpion-like, coiled like the tail of a scorpion
semilunar—crescentic, or resembling a half moon
semiovate—half egg-shaped
senile—pertaining to old age
septal radii—radiating ridges taking the place of septa in certain corals
septate—with partitions or septa
septum—partition; in corals, the radiating calcareous plates; in cephalopods, the transverse partitions between the chambers
serrate—notched like a saw
setiferous—bristle-bearing
sigmoid—curved like the Greek letter Σ (sigma)
sinistral—left handed, reversed coiling of some gastropod shells
sinuate—wavy, winding
sinuosity—notch or incision forming a wavy outline
sinus—impression in the surface or margin of a shell
siphonal funnel—siphonal projection from the septum of a cephalopod shell
siphonal lobe—lobe in the suture of an ammonoid shell, corresponding in position to the siphuncle
siphuncle—tubular canal passing through the air chambers in the shells of cephalopods
slickensides—polished or striated surfaces on rock due to motion under great pressure
sockets—hollows in the brachial valve of brachiopods for the reception of the teeth of the opposite valve
spatulate—shaped like a spatula; spoon-shaped
spheroidal—globose, of the form of a spheroid
spiniform—spine-like
spinulose—spine bearing
spondylium—spoon-shaped cavity under the beak of pentameroid brachiopods
squamous—scaly, covered with scales
stalk—stem of crinoids
stellate—star-shaped; arranged in star-like manner
stipe—stalk or stem in plants
stock—main stem or trunk
striae—fine radiating surface lines of shells
stylolites—peculiar columnar and striated rock form seen in limestones at the junction of two layers
sub—in composition indicates a low degree: sub-angular—rather angular; sub-carinate—somewhat toothed, etc.

subfusiform—more or less spindle-shaped
subglobose—more or less globose
sublunate—approaching the form of a crescent
suborbicular—nearly circular
subpentahedral—irregularly five-sided
subpyramidal—approximately pyramid-shaped
subquadrangular—between quadrangular and oval
subquadrate—nearly but not quite square
subspheroidal—imperfectly spheroidal
subtruncate—irregularly cut off
subturbinate—approaching top shape
sulcation—a furrow or channel
sulcus—a furrow
superior—higher in position
suture—in cephalopods, the line of junction between shell and septum, seen on breaking away the former; in gastropods, the external line of junction between the several whorls; in trilobites, the dividing line between fixed and free cheks, commonly called *facial suture;* in crinoids, the line of junction between adjacent plates

tabulae—transverse, continuous partitions or floors in corals, etc.
tabulate corals—group of corals in which the tabulae cross plates are prominent, while the septa are faintly or not at all developed e. g. Favosites, Aulopora, etc.
talus—the mass of rocky debris which lies at the base of a cliff, having fallen from the face of the cliff above
teeth—articulating projections on the margins of the valves of bivalve shells
tegmen—vault or cover of the calyx in crinoids
terebratuloid—like the recent genus Terebratula
terete—cylindric or slightly tapering terrigenous—derived from the land test-shell
tetracoralla—the old group of rugose corals, built on the plan of four
tetrameral—on the plan of four
theca—the proper wall of the individual corals
thoracic—pertaining to the thorax
thorax—central part of the body of the trilobites
trabeculae—projecting bars
trigonal—three-angled
trihedral—with three equal faces
tripartite—divided into three parts
tripetalous—three leaved or petaled
trochiform—in form like a Trochus or top shell
tubercle—small swollen projection
tuberculiform—in form like a tubercle
tuberculous—having or resembling tubercles
tubicola—an order of marine worms which build calcareous or other tubes
tumid—swollen, inflated
turbinate—top-shaped

**umbilicus**—external opening of the hollow axis of a loose coiled shell
umbo—area about and including the beak in pelecypods and brachiopods
unconformity—irregularity in the succession of rock beds indicating an intervening period of erosion

**valvular**—pertaining to a valve
varix—row of spines, a ridge or other mark, denoting the former position of the lip on the shell of a gastropod (plural varices)
vaulted—arched
ventral—pertaining to the lower side, or venter
ventricose—strongly swollen, or bulging
vesicular—bearing vesicles, or hollow cavities
vestibular area—area surrounding the cell apertures of some bryozoa; often depressed
viscera—the internal organs of the body

**whorl**—single volution of a coiled shell
wing—posterior larger expansion along the hinge-line of a pelecypod

**zoarium**—aggregates of the polypites of a bryozoan colony
zooecium—the bryozoan cell
zooid—one of the " persons " or individuals of a zoarium

# INDEX

The superior figures tell the exact place on the page in ninths; e. g. $190^{3}$ means page 190, beginning in the third ninth of the page, i. e. about one third of the way down.

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# SCALE INSECTS OF IMPORTANCE

AND

# LIST OF THE SPECIES IN NEW YORK STATE

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# CONTENTS



[1] A general account and bibliography of each is given.

# SCALE INSECTS (DIASPINAE) OF IMPORTANCE

**Ord. Hemiptera; Fam. Coccidae**

## INTRODUCTION

"There is no group of insects which is of greater interest to horticulturists today than that family which includes the creatures popularly known as 'scale insects' and 'mealy bugs.'" These words, written 20 years ago by Prof. Comstock, the first American to make a close study of the characters presented by the female scale insect, are still true. These insignificant animals attack almost every tree and shrub and many herbaceous plants, and certain species have caused serious injuries and, under favoring conditions, are capable of inflicting enormous losses on our nursery, orchard and greenhouse interests. Their minute size, resistance to insecticides and marvelous prolificacy render them formidable pests. Scientific men have awakened to the importance of this group, and scale insects are being studied as never before. Large numbers of new species have been characterized within the last five years, and many important biologic facts relating to this family have been ascertained.

**Characteristics.** The popular name, "scale insects," is truly descriptive of the species belonging to one subfamily, the Diaspinae, or armored scales, since the insects themselves are covered with a scale, a secretion usually beginning on the recently hatched young as a mass of white, cotton-like threads (pl. 1, fig. 3), which mats down and extends to form a shield-like covering for the tender insect (pl. 1, fig. 4). These forms are frequently known as bark lice, because most of the species are found on the bark of trees or shrubs, and it is a very good descriptive name. The scale insects, like all others belonging to the same class, originate from eggs. Sometimes the eggs are deposited under the scale (pl. 1, fig. 8) and remain unhatched over winter, or they may develop into young within the body of the female (pl. 3, fig. 10), and then the insect is called viviparous, or more strictly, ovoviviparous. The young in either case are minute creatures possessing six true legs, with good locomotive powers for such small beings, and provided with eyes and a pair of antennae or feelers. That is, they have the normal characteristics of very young insects. The secretion of the scale, which usually begins within a few days after the young hatch, is followed by remarkable changes. The eyes, antennae and legs disappear, and there results an animated, sucking, sac-like creature (pl. 1, fig. 10) with apparently no

other aim or power than the perpetuation of the species. This, in brief is the story of the female scale. It is different with the opposite sex. The scale, usually of a different form, is secreted by the young (pl. 2, fig. 6), and the same process goes on till the second molt, and then rudiments of limbs, antennae and wings are developed, and later appears the minute two-winged creature (pl. 3, fig. 12), which forsakes its sheltering scale and looks for a mate. This tiny insect lost its appendages while living under the protecting scale, and in time developed others much more delicate and refined.

Other scale insects are not protected by a shield of excreted matter and cast skins as are those mentioned above. They vary much in general appearance and habits. Some live in galls, others, like Kermes, resemble and are frequently taken for galls, while still others may be found in ants nests. The soft, brown Lecaniums are among the most common unarmored scale insects, and they can usually be distinguished by their oval, somewhat hemispheric bodies. The more typical Coccidae are represented by the "mealy bug," Dactylopius longispinus Targ., and the elm bark louse, Gossyparia ulmi Geoff. The former is common in greenhouses and the latter is found in considerable numbers on elms in many cities and villages. Neither of these lose their appendages with the first molt, as do the armored scales, and they retain the power of locomotion to a certain extent, at least. Coccidae belonging to this group are usually covered with a whitish, protective excretion, which is, for example, cotton-like in Gossyparia and granular in the "mealy bug."

**Number of species.** The number of described species of scale insects is very large. A check list of the Coccidae of the world[1], published by Prof. T. D. A. Cockerell in 1896, lists over 800 species, and a supplement[2] to this adds over 300, making a total of about 1100. Some of these will doubtless prove to be varieties, but new species are constantly being added to the list. A most interesting study of the forms occurring in the state of Massachusetts has been prosecuted by George B. King, of Lawrence (Mass.), who has succeeded, by collecting and compiling, in bringing together a list of 110, aside from several unidentified, species of scale insects known to occur in that commonwealth. Compilation of earlier records and the aid generously given by other entomologists have made it possible to prepare a list of 78 species of scale insects known to occur in New York state (*see* p. 354). Many additions will doubtless be made to this list by farther collecting.

1 Illinois state laboratory of natural history. Bul. 1896, v. 4, art. 9.
2 " 1899, v. 5, art. 7.

**Injuries.** The harm done by scale insects is seldom appreciated till it is too late. The scales may be noticed on the bark in considerable numbers, but so long as the tree shows no marked injury, the majority of people are inclined to believe that but little harm has been done. They appear to overlook the fact that a tree, like a man, may put forth every possible effort to sustain itself and apparently succeed in doing so, only to collapse suddenly at the end. Every living scale insect, after it has become established, is an automatic pump drawing the vital fluids from the host plant through a slender, hair-like beak or proboscis (pl. 3, fig. 10). The amount insects are capable of abstracting in this way from a tree is truly surprising. I have repeatedly seen showers of honeydew falling from elms badly infested with the elm bark louse, the excretion being so copious as to keep the walk beneath wet even on good drying days. This abundant excretion is not seen in the case of the armored scales, like the species to be considered later, but the production of their firm, protective coverings, as well as the nutrition of the thousands of insects, must make an enormous draft on the infested tree. This is proved by the fact that not infrequently trees are unable to withstand the drain and succumb. The injury these species can inflict is in a measure directly proportional to their productivity. A moderately prolific species possessing the ability to develop several generations in a season is one to be feared, because under favoring conditions a much larger number of individuals might be produced than would be possible for a much more prolific species which was limited by nature to one generation annually. It is the same for one year as the relation existing between arithmetical and geometric progression. This is why the San José scale is so dangerous. It is not only moderately prolific, but it develops a number of generations in a season. It has been estimated that in one year in the latitude of Washington (D. C.) a single female might produce, all conditions such as food supply, etc. being favorable, the enormous number of 3,216,080,400 descendants.

**Means of dispersal.** This is an extremely important matter, particularly to the man whose trees are free from these pests. The period when any of the scale insects to be considered below can travel of their own free will is very limited and, excluding the males, which may be disregarded in this connection, they are wingless and their crawling powers by no means great. These scale insects depend almost entirely on some external agency to transport them even from tree to tree, unless the limbs interlock. It has been demonstrated by Prof. W. G. Johnson that the

young of the San José scale are carried short distances by a strong wind, and there is no reason why those of other species might not be conveyed in the same manner. Evidence of one kind and another has been accumulating to show that active young of the scale insects are carried by other insects, birds and animals from tree to tree. It is also well known that these forms are most readily transported long distances on young trees and plants. This means is by far the most important, and fortunately is the one most readily controlled. Methods of preventing this dissemination will be considered under an appropriate head after the discussion of several injurious forms.

**Certain species of value.** Some Coccidae, or scale insects, are of economic importance on account of their products. The well-known cochineal is derived from the dried bodies of a scale insect, Coccus cacti Linn., which, as is well known, lives on several species of Cactaceae in Mexico. Prof. Comstock states that this insect is also reared in India, Spain and other countries. This species or a closely allied form is found on wild cactus in Ceylon, as stated by Mr Green.[1] Another species, Tachardia lacca Ker., excretes the substance from which is made the "lac," or shellac, of commerce, and from the insect itself a crimson pigment known as "lake" is obtained. This insect lives on species of Ficus and on Croton lacciferum. Prof. Comstock has described two American species belonging to this genus, Tachardia larreae and T. mexicana. The former occurs on the creosote plant, Larrea mexicana, a plant growing in the southwestern part of the United States and in Mexico, and in Prof. Comstock's opinion this "lac" insect might prove of economic importance. The latter species was found on a twig of mimosa from Tampico (Mex.) It is interesting to record that Prof. Cockerell has subsequently described four other American species of this genus. The waxy excretion of a Chinese scale insect, Ericerus pela Westw. is used in the manufacture of candles in that country. A near relative of our Gossyparia ulmi Geoff., the Gossyparia mannifera Hardw., "is found upon Tamarix mannifera Ehr., a large tree growing upon Mt Sinai, the young shoots of which are covered with the females, which, puncturing them with their proboscis, cause them to discharge a great quantity of a gummy secretion, which quickly hardens and drops from the tree, when it is collected by the natives, who regard it as the real manna of the Israelites."[2]

1 Green, E. E. Coccidae of Ceylon. 1899. p. 3.

2 Westwood, J. O. Introduction to the modern classification of insects. 2 : 449.

**Recognition of scale insects.** The majority of farmers and fruit-growers experience great difficulty in distinguishing between the various forms, and such will continue to be the case for some time to come; but it is hoped that the illustrations accompanying this account will enable the non-scientific man to identify certain of these vexatious forms with some approach to accuracy. It must ever be borne in mind, however, that, in attempting to identify an armored scale insect by external appearances, we are not studying the insect itself but a secretion subject to considerable variation as a result of climatic and other external influences. Scale insects occurring on trees near a railroad or in a smoky locality may have their characteristic appearance much obscured by particles of soot and dirt, and those living on trees infested to a considerable extent with plant lice or other honeydew-excreting forms, may be more or less covered with a sticky layer of dirt. These variations in appearance and the minuteness of scale insects render their correct determination very difficult for one who has not given the group special study.

**Key based on superficial characters of species treated.** The above statement regarding the variability in the appearance of the scales of these insects must be constantly borne in mind, and identifications made in this manner, unless by an expert, should be regarded as provisional. An effort should be made to secure both young and full-grown specimens and, if possible, on different pieces of bark, some having few and others having numerous individuals, as this will give a better idea of the characteristics of the insect. A good magnifying glass or lens should be used in examining the scales. A very serviceable one can be obtained for from one to several dollars, and it is invaluable to the nurseryman and fruit-grower in enabling him to examine suspicious appearances more closely. The characters given below do not apply to any of the oval, usually somewhat hemispheric brown species of Lecanium, but only to the species of armored scale insects treated of in detail.

The species briefly characterized below are arranged in the order of their present abundance in New York state; and, if the description in the first paragraph does not apply, pass to the second and so continue. It may frequently happen that the specimen does not agree with the descriptions given in any of the paragraphs, and in that case it is most probably one of the species not treated, of which there are many; and the way to ascertain the identity of such an insect is to send specimens to an entomologist.

1 Adult female scales elongated, slender, pear-shaped, usually slightly curved, almost $\frac{1}{8}$ inch long and brown. Numerous white eggs may be

found beneath the scales in winter. Occurs on many trees and shrubs. (pl. 1) Appletree bark louse, Mytilaspis pomorum

2 Adult female scales irregularly expanding from a slender tip, about $\frac{1}{10}$ inch long and white or a dirty white. Purplish eggs may be found under the scales in winter. Male scales slender, white, with three ribs. Common on fruit trees and shrubs. (pl. 2)

Scurfy bark louse, Chionaspis furfura

3 Adult female scales circular or oval, usually a dark gray to black, about $\frac{1}{12}$ inch in diameter, and with the brick red cast skin or exuviae to one side of the center. Margin of the scale usually well defined. The young scales remain white or pink for a considerable time and usually have a well developed nipple and an inconspicuous ring. Very common in New York state. On fruit and other trees, specially maple and elm. (pl. 5) Putnam's scale insect, Aspidiotus ancylus

4 Adult female scales circular, gray or yellowish gray, about $\frac{1}{16}$ inch in diameter and with the yellowish cast skin or exuviae central. Young scales dark gray, sometimes almost black, with a distinct central nipple and a grayish ring. Green tissues are frequently stained purplish by this insect. May occur on many trees and shrubs. (pl. 3)

San José scale insect, Aspidiotus perniciosus

5 Adult female scales nearly circular, usually a gray or a dark gray, with a diameter of $\frac{1}{8}$ inch and with the yellowish or red cast skin or exuviae a little to one side of the center. The gray, dirt-spotted, outer portion of the scale is usually continuous with the outer layer of rough bark, but this does not hold on smooth bark. The young scales are white or brownish and have a distinct nipple but almost no ring. They are sometimes arranged very prettily at almost equal distances. Occurs on fruit trees, specially plums. (pl. 4)

European fruit scale insect, Aspidiotus ostreaeformis

6 Adult female scales nearly circular, usually a yellowish gray, about $\frac{1}{12}$ inch in diameter and with the yellowish larval skin or exuviae a little to one side of the middle. Young scales white or pinkish, with the nipple and ring, specially the latter, not well marked. Occurs on fruit trees. (pl. 6) Cherry scale insect, Aspidiotus forbesi

7 Adult female scales nearly circular, almost white, about $\frac{1}{12}$ inch in diameter and with the yellowish larval skin or exuviae a little to one side of the center. Young scales yellowish or white. Confined in New York state to greenhouse plants, common on ivy. (pl. 7)

White scale insect, Aspidiotus hederae

## Appletree bark louse

*Mytilaspis pomorum* Bouché

PLATE I

This is the most common scale insect found on fruit trees in New York, and in some localities it is very abundant and destructive, particularly to poplars and ash in the vicinity of Albany. This pest has been repeatedly noticed in agricultural and entomologic journals, and it is a frequent source of complaint at the present time. A few of the more important articles treating of this insect are given in the brief bibliography below. This European species was probably brought to America on early importations of fruit trees, and now it is known to occur all over the world, as stated by Dr L. O. Howard. It has been described scientifically several times, on each occasion receiving a different name, and it also passes under the common name of oyster shell bark louse. The popular designation given above is extensively used, and it is preferable on account of its being more characteristic of the species.

**Description.** The adult female scales can easily be recognized by a comparison with the greatly enlarged figure 7 or with figure 9, which latter represents a number in natural size on poplar bark. The adult scale is about 3 mm, or $\frac{1}{8}$ inch long, usually slightly curved and widening from a slender tip to a broad, rounded posterior end. The scale has at its pointed or anterior end a usually yellowish, very small pellicle, the first cast skin of the young, and a small scale three times its size attached to it. There is also a larger or second cast skin, and to it is attached the larger or chief part of the scale, which is a variable brown and marked with curved transverse lines or wrinkles. The first cast skin can be detected only on microscopic examination. The female insect found underneath the covering scale is represented in figure 10. The male scale is smaller, and is shown in figure 6. A female scale turned over in winter presents the appearance represented in figure 8. The shriveled, yellowish or brown body of the female occupies the anterior portion of the scale cavity, while in the posterior part are numerous oval, white eggs, shown greatly enlarged in figure 1. The minute, yellow, recently hatched scale insect is represented in figure 2, and the condition of a number shortly after establishing themselves on a twig, in figure 3. The appearance of the young after it has secreted a protecting scale is represented in figure 4, a few being shown much enlarged in figure 5.

**Life history.** This insect completes the round of life once a year in this latitude, though in the southern states two generations may be pro-

duced. The winter is passed in the egg under the protecting scale of the female, the young appearing from the middle of May to early June, and in the case of badly infested trees parts of the twigs may be literally yellow on account of the abundant crawling specks. Prof. Lowe has observed them as early as May 7 at Geneva (N. Y.) They soon settle in a place and begin sucking nourishment from the underlying bark tissues, and in about two days long, white, waxy filaments extend from the back of the young, and, where they are numerous, the infested branch is adorned with patches of woolly-appearing matter, as shown in figure 3. This excretion mats down and soon forms a protective covering. Close inspection shows this to be composed of a cast skin and a larger scale formed by the matted filaments adhering to it. Such half-grown insects, represented in figures 4 and 5, are about six weeks old. Another molt occurs later, and to this second cast skin a much larger scale is attached. The first cast skin and its scale are on top of the anterior part of the second, but are easily dislodged and therefore may not be observed. The fully developed female may be found beneath the larger scale about the first of August, egg-laying beginning soon and being completed by the latter part of the month or early September. One female deposits from about 50 to 100 eggs. Prof. Comstock states that, while he found the male scale rare on appletrees at Washington, it was abundant on other kinds of trees. The attacks of this insect are confined almost wholly to the bark, though there are a few records of the species occurring on fruit.

**Food plants.** This species is of greatest importance on account of its depredations on fruit trees, but it also occurs on a large number of other plants. The brief list of food plants brought together by Dr Lintner in his 11th report includes most of the more important species. It is as follows: apple, plum, pear, raspberry, wild cherry, wild gooseberry, red currant, sugar and swamp maples, white and black ash, birch, poplar, willows, linden, horse-chestnut, elm, etc. Dr L. O. Howard, writing of this insect in 1895, gives two lists of food plants, a number of which are not represented in the above enumeration, and he proceeds to state that, though no structural differences have been found between the forms on these varied food plants, he can hardly avoid the strong suspicion that certain of these will not interbreed, and that eventually distinguishing characteristics will be found to exist.

**Natural enemies.** A small hymenopterous maggot was observed by Dr Fitch to live on the eggs of this pest. What was in all probability the same parasite was described by Dr Le Baron some years later as A p h e l i-

nus mytilaspidis, which he found had destroyed from about 50% to 60% of the scales. Aphelinus fuscipennis How. is recorded as a most efficient parasite of this scale in California. Aspidiotiphagus citrinus Craw. has been reared from this pest in that state. The accompanying figure will give a good idea of the appearance of these tiny Chalcids. The best evidence of their work is the small circular holes in the dead scales, orifices by which these little friends have escaped. Aphelinus abnormis How. is another parasite of this bark louse. Anaphes gracilis How. and Chiloneurus diaspidinarum How. have also been reared from this insect.

Fig. 1 Aspidiotiphagus citrinus Craw., greatly enlarged (After Howard. Insect life. 1894. 6 : 229)

Coccinellid or lady bug larvae prey on this species, and certain mites, Tyroglyphus malus Shimer, are also credited with this habit. A French investigator has apparently shown that this Tyroglyphus does not feed on the eggs, but a species is described, under the name of Hemisarcoptes coccisugus Lign., which does valiant service in destroying them.

Three European birds, the blue tit, the long-tailed tit and the tree creeper are known to feed on this insect.

**Remedies.** The hatching of the young the latter part of May or in early June renders it practicable to control this insect by applying a contact insecticide June 1 or later in order to kill the young scale insects before they are protected by a thick scale.

*Bibliography*

**Fitch, Asa.** N. Y. state agric. soc. Trans. 1854. 14 : 735–42 (general account of injuries and distribution, as Aspidiotus conchi-

formis Gmel.); Noxious, beneficial and other insects of New York state. 1st and 2d rep'ts. 1856. p. 31–38.

**Walsh, B. D.** Ill. state hortic. soc. Trans. 1868. Separate as report of acting state entomologist. p. 34–53 (general account, as Aspidiotus conchiformis).

**Le Baron, William.** Chalcideous parasite of the appletree bark louse. Am. ent. and bot. 1870. 2 : 360–62 (parasites, description and habits of Aphelinus mytilaspidis).

**Osborn, Herbert.** Entomological notes for the year 1882. Ia. state hortic. soc. Trans. 1882. 1883. p. 212–13 (brief notice).

**Riley, C. V.** Insects of Missouri. 5th rep't. 1873. p. 73–96 (general account, described as Mytilaspis pomicorticis).

**Comstock, J. H.** U. S. dep't agric. Rep't of ent. 1880. p. 325–26 (synonymy, characters, life history).

**Lintner, J. A.** Injurious and other insects of New York. 4th rep't. 1888. p. 114–20 (general account).

**Howard, L. O.** Some scale insects of the orchard. U. S. dep't agric. Yearbook. 1894. p. 254–59 (general account).

**Lowe, V. H.** Inspection of nurseries and treatment of infested nursery stock. N. Y. agric. expt. sta. Bul. 136. 1897. p. 576–82 (general account).

**Lochhead, William.** San José and other scale insects. Ont. dep't agric. Toronto. 1900. p. 40–41 (brief account).

## Scurfy bark louse

*Chionaspis furfura* Fitch

PLATE 2

This common and destructive species is not an imported insect, like the preceding form, but the two occupy in New York state nearly the same rank as pests of considerable economic importance. The scurfy bark louse frequently appears in large numbers, specially on recently set fruit trees, which occasionally become so covered with the pest as to look at a little distance as if they had been whitewashed. Closer inspection shows the infested trees to be nearly covered with dirty white, scurf-like patches, and it is from this that the popular name of the insect has been derived.

**Description.** Sometimes this insect occurs in thick, matted, dirty masses, and then the form of the individuals is much obscured. There is usually some place on the infested plant where the females are somewhat isolated and have the general appearance represented in figure 7, which shows a group of females with two males in the lower right hand corner. A closer examination of one scale will reveal the details illustrated in figure 4. The female scale consists of a very small yellowish pellicle (usually two are present), a larger dark scale and a very much larger, irregularly shaped, whitish scale. Figure 1 shows this structure in greater detail. The male scales are elongated, with a small yellowish pellicle and a much larger, tricarinate white scale, as represented somewhat enlarged in figure 8 and much more so in figure 6. A rupture of a female scale in the fall or winter reveals the purplish eggs beneath (fig. 1), and, when one is turned over, the shrunken body of the parent and the mass of eggs is exposed (fig. 5). The active, reddish young is represented in figure 2, and the partly grown individuals, showing the yellowish pellicle and the dark smaller scale, in figure 3. The full-grown female, as she appears under the scale before egg deposition begins, is represented in figure 9.

The male was not reared, and, as a matter of fact, it is rarely observed. Prof. Comstock's description of this form is as follows:

Yellow marked, with irregular reddish-brown spots; thoracic band reddish brown, sometimes darker than the other markings. Length of body including style, .62 mm (.02 inch); length of style, .18 mm (.006 inch). On each side of the anterior part of the thorax there is a black spot which resembles an eye.

The accompanying illustration of the male and its pupa will aid greatly in its recognition.

**Life history.** The development of this species is very nearly the same as that of the preceding form. The winter is passed in the egg underneath the protecting scale of the female. The young appear in this latitude about the same time as do those of M y t i l a s p i s p o m o r u m, viz from about the middle to the last of May. They soon establish themselves at favorable points on the bark of the trunk and branches and begin drawing sustenance from the underlying tissues through the delicate, thread-like haustellum or beak. Occasionally the young may establish themselves in some numbers on fruit. Such a case was brought to notice this season. The insects were at the blossom and stem ends of the apples and each was surrounded by an irregular, reddish area. A considerable proportion of the fruit was infested in one orchard in

Greene county. The appearance of the insect about six weeks from birth is well shown in plate 2, figure 3. Then there are yellowish exuviae and a dark grayish scale about 1 mm or $\frac{1}{25}$ inch long. Later the conspicuous larger, white portion of the scale is excreted, and the eggs may

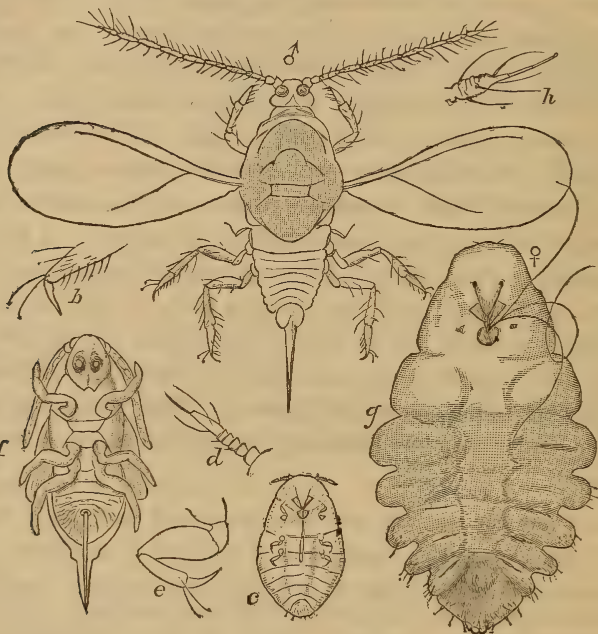


Fig. 2 Chionaspis furfura: Adult male above; *b* foot; *h* tip of antenna of same; *c* larva; *d* antenna; *e* leg of same; *f* pupa; *g* adult female removed from scale—all enlarged, *b*, *d*, *e*, *h* much more than the others. (After Howard. U. S. dep't agric. Yearbook. 1894)

be found the latter part of August or in early September to the number of 30–75 under one scale, where they remain dormant till the following spring. It is stated that two and possibly three generations may develop in one season in the southern states.

**Food plants.** This scale insect is specially abundant in New York on apple, pear, Japan quince and blackcap raspberry bushes. Dr Howard found it so numerous on mountain ash in the Catskill mountains, that hardly a twig or branch was uninfested. It has also been recorded on the following: crab apple, peach, quince, black cherry, choke cherry, wild red cherry, shad bush, cherry currant, wild flowering currant, black walnut and black alder (Clethra alnifolia). The identity of the insect on all these food plants has not been established beyond question. I have since learned that Mr King has succeeded in bringing the list up to 23 food plants; so this species can be classed as a general feeder.

**Distribution.** This insect is well distributed over New York state and is present in many other states, as shown by the following compiled list: Massachusetts, Rhode Island, Connecticut, New York, New Jersey, Delaware, Pennsylvania, Maryland, Virginia, West Virginia, District of Columbia, Kentucky, Tennessee, Georgia, Kansas, Mississippi, Ohio, Indiana, Illinois, Missouri, Iowa, Nebraska, Utah, South Dakota and California. It has also been recorded from Ontario, Nova Scotia, New Brunswick and Prince Edward Island. The absence of record by no means implies that the scale is not known in the omitted states. It has also been recorded from England, having been carried there on Ribes sanguineum. Dr Howard, in his account of this insect, alludes to

Fig. 3. Ablerus clisiocampae, female greatly enlarged. (After Howard. Insect life. 1894. 7:7)

an early record where it is stated that the appletree bark louse is gradually supplanting this pest, and proceeds to state that the former is apparently the hardier, and that he believes that it will in time take the place of Chionaspis furfura. Both species have been in New York state for about 50 years at least, and it does not appear that the native form has been materially checked by the presence of a more hardy rival.

**Natural enemies.** One hymenopterous parasite, Ablerus clisiocampae Ashm., has been bred from this scale insect by Dr Howard. Two Coccinellids, Hyperaspidius species and Chilocorus bivulnerus Muls., the twice stabbed lady bug, prey on this pest. The latter is stated to be a specially valuable enemy.

**Remedies.** The recommendations for controlling this insect are the same as those advised for the preceding form, to which the reader is referred.

*Bibliography*

**Fitch, Asa.** N. Y. state agric. soc. Trans. 1856. 16 : 352–53 (original description as Aspidiotus furfurus); Noxious, beneficial and other insects of New York. 3d–5th rep'ts. 1859. p. 34–35 ¶ 54.

**Walsh, B. D.** Ill. state hortic. soc. Trans. 1868. Separate as rep't of acting state ent. p. 53–55 (general account).

**Comstock, J. H.** U. S. dep't agric. Rep't of ent. 1880. p. 315–16 (synonymy and description).

**Osborn, Herbert.** Entomological notes for the year 1882. Ia. state hortic. soc. Trans. 1882. 1883. p. 291–92 (brief general account).

**Howard, L. O.** U. S. dep't agric. Yearbook. 1894. p. 259–61 (general account).

**Cooley, R. A.** Coccid genera Chionaspis and Hemichionaspis. Mass. agric. expt. sta. Special bul. Aug. 10, 1899. p. 23–29 (synonymy, bibliography and general account).

**King, G. B.** A new variety of Chionaspis furfura Fitch and notes on other species. Psyche. 1899. 8 : 334–36 (a variety described, food plants and distribution given).

**Cockerell, T. D. A.** Note on the pigments of the coccid, Chionaspis furfura Fitch. Science. Ap. 27, 1900. 11 : 671 (note on color and changes obtained by potassium hydrate).

**Lochhead, William.** San José and other scale insects. Ont. dep't agric. Toronto. 1900. p. 42–43 (brief notice).

## Pernicious or San José scale insect

*Aspidiotus perniciosus* Comstock

PLATE 3

This insect is known by hearsay, at least, to almost every fruit-grower and farmer in the eastern United States. It has recently become established in a number of widely separated localities in New York state, and is now the object of considerable anxiety to both horticulturists and nurserymen. This pest is very destructive in some of the more southern states, and even in New York, when allowed to increase without restriction, it causes considerable damage. Its ability to inflict so much injury

depends largely on its inconspicuousness and great prolificacy. So marked are these that several trees may be literally covered with the pest before the owner is aware of its presence, and this in spite of his being on the watch for the enemy.

Those who unfortunately have the insect on their premises find that it is a difficult pest to combat, and that only the most thorough work will produce the desired results. Carefulness to avoid this scale insect and a strong desire to learn about its appearance and life history, are ordinary precautions every fruit-grower should take, and this spirit should be encouraged wherever found. Ridiculing such precautions in an attempt to make light of the danger, and sensational statements regarding the destructiveness of the insect, are both to be deprecated. Neither the nursery nor the horticultural interests of New York state will be ruined by this pest, but those who neglect the proper precautions may suffer considerable loss. The ultimate result will be better care of many orchards and a more just appreciation of the powers for good or evil possessed by insects.

**Destructiveness in New York state.** Continuous fighting, even in this latitude, is the price of practical immunity from danger in places where the scale has become established. There are several orchards within 20 miles of Albany where this pest has been for the past eight to 10 years. Some trees have been killed outright, others ruined and many seriously dwarfed and stunted. The record would have been worse, had the pest not been fought, and, on the other hand, it might have been much better if recently discovered facts had been accessible earlier. I allude in particular to the value of petroleum, specially of the mechanical emulsion. There are a number of records of this pest doing little damage in a locality till some eight years after its establishment, and then suddenly with favoring conditions it may become very abundant and injurious. The possible rapidity with which this scale insect may increase in this state is strikingly shown by an apple twig 15 inches long of 1898 growth which on receipt at the end of that season was nearly covered with half-grown scales. That is, the pest was able to keep up with the rapidly growing tree, and at the end of the season a large proportion of the new wood was nearly covered with half-grown scale insects. G. G. Atwood, now in charge of the inspection work in the state informs me that he has repeatedly noticed that this pest thrives best on vigorous trees.

**Indications of the presence of the scale.** This scale insect is so minute that it has usually escaped the observation of any but specially trained eyes till it had become quite abundant. People are learning what

to look for now, and the pest is usually discovered earlier. Trees which have been badly infested for some time have a rough bark covered with dark gray, scurfy patches, and, if this be scratched with a knife or finger nail, an oily, yellowish substance will be crushed from the living insects under the scales. This insect breeds so rapidly that it is not uncommon to find large numbers on a tree previously comparatively free. In that event the bark may be literally covered with recently established scales and not appear very rough. There is, however, a peculiar, granular look, and those familiar with the bark of a rapidly growing tree are aware that some change has taken place. There is nothing like a good magnifier in these cases, and, if this shows hundreds of circular, black or dark gray objects, with dot and ring, or lighter gray, yellowish marked scales, send a sample of the bark to somebody competent to identify the trouble. Cutting into the bark under a San José scale is almost sure to reveal a reddish discoloration of the green tissues beneath. Lenticels occasionally deceive people, and I have seen fungous growths which at a little distance looked much like masses of young pernicious or San José scale. An infestation of any extent on fruiting trees is almost sure to show itself on the leaves and fruit, the reddish blotches being more conspicuous than the insects (fig. 3). The reddening of the fruit is not absolute proof that San José scale is present, because I have seen nearly the same effects produced by Chionaspis furfura Fitch. The pear illustrated shows a condition which obtains in badly infested orchards in July. Late in August the blossom end and sometimes the other may be literally incrusted with patches of young and old scales like the one represented in figure 7. A close examination of a slightly infested tree may result in finding a very few scales somewhere on the bark, most frequently near a bud or some protecting elevation, and, in these cases, the piece of infested bark should be cut away and sent to an entomologist for identification.

**Description.** This scale insect is so minute that a superficial description must be drawn in most general terms. The twig, fruit and leaf shown in figures 3, 4 and 5 of plate 3 represent a very characteristic appearance in July in a pear orchard badly infested by this pest. A dark grayish or yellowish area on the bark may be caused by a mass of these scales. An enlargement of the darker patches will show a condition much like that represented in figure 7. Adult, yellowish gray scales may be found surrounded by hundreds of tiny black ones. The form of the larger scales is modified somewhat by the degree of crowding, and it is common to find a number of them adhering in a patch; but a close examination of the well

marked adult female scale reveals the following characteristics. It is almost 2 mm, or $\frac{1}{16}$ inch, in diameter, nearly circular, grayish, with a central darker nipple surrounded by one or more rather well-defined yellowish rings (fig. 9). The smaller scales are nearly black, with a central nipple, and one or two grayish rings as represented in figure 13. The largest scales are just about the size of the head of an ordinary pin, while the smaller ones are mere dots, as represented by the black specks on the twig, figure 5. Sometimes the female scales have a distinct yellowish shade, as shown in figure 6. The yellow, usually somewhat kidney-shaped female insects may be found under the scales. A gravid female is shown much enlarged in figure 10. Note the oval young within her body and the slender proboscis apparently composed of two filaments but in reality of four. The yellow, active young is shown much enlarged in figure 11. The antennae, six legs and slender proboscis are all present. The young appear as minute specks when on the trees. They soon cover themselves with a white excretion, and then they appear like white dots surrounded by red, whenever they establish themselves on green fruit or bark (fig. 2). The form of the white scale and the colored area around it are represented in detail in figure 1.

The male scale may be easily recognized by its elongated shape with the nipple near one end (fig. 8). The delicate, two-winged male is represented much enlarged in figure 12.

**Life history.** The winter is passed by this insect in a partly grown, dormant condition. Vital activities are resumed with the approach of warm weather, and the first outward indications of life are seen in the appearance of winged males and later of the crawling young, the latter of which appear in this latitude toward the last of June. The life history of this insect has been studied in detail at Washington (D. C.) under the direction of Dr L. O. Howard; and from his account most of the following details are taken. The females continue to produce young for a period of about six weeks, each averaging about 400, or from nine to 10 every 24 hours. This is an ovoviviparous species. That is the eggs develop within the mother and the young are born alive. They may be seen as tiny yellow specks escaping from under the maternal scale, from which they wander in search of a favorable place to establish themselves. This pilgrimage occupies relatively few hours (an average of a little over $27\frac{3}{4}$ hours, according to Prof. Lowe), and the young soon establishes itself, works its slender proboscis through the bark and begins to draw nourishment from the plant. The development of the

scale begins, even before the young has selected its feeding place, as very minute, white, waxy filaments, which spring from all parts of the body, rapidly become thicker and slowly mat down to form the circular, white scale with a depressed ring and central elevation (pl. 3, fig 5). This white scale gradually becomes darker, and in a few days it has assumed a black or dark gray color, with one or more lighter rings, as represented in plate 3, figure 13. The skin is cast for the first time 12 days after the young appear. The molt, as is true of all species of Aspidiotus, consists of a splitting of the old skin around the outer edge of the flattened insect, the upper part being attached to the scale and the lower portion forming a ventral scale next the bark. Prior to this molt the sexes are indistinguishable, and both lose legs and antennae at this time. The males may now be recognized by the large purple eyes and the elongate, pyriform body, while the females are eyeless, and are practically flattened sacs with only the slender, central sucking bristle. Six days later, or when the insect is 18 days old, the male molts to the pro-pupa (fig. *b*), and the male scale becomes an elongated oval in form. The antennae,

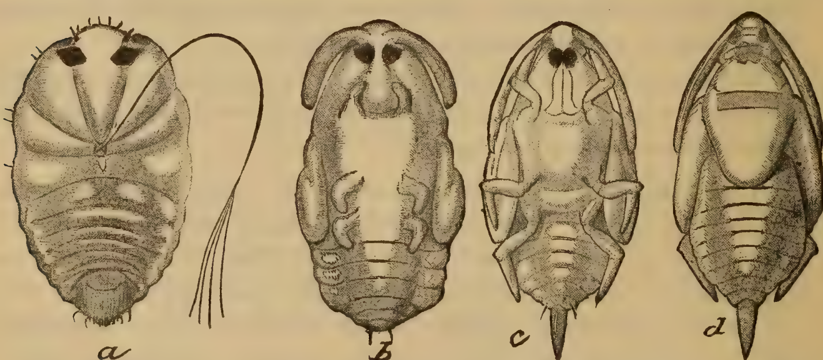


Fig. 4 Development of male insect, *a* ventral view of young after first molt, *b* same after second molt (pro-pupa stage), *c* and *d*, ventral and dorsal views of true pupa. (After Howard U. S. dep't agric. div. ent. Bul. 3, n. s. 1896)

legs and wings now appear in a very rudimentary condition and in two days become much better shaped, when the change to the true pupa (fig. *c*, *d*) takes place. Four to six days later, or from 24 to 26 days from birth, the mature, two-winged males back out from under their protecting scales. The female undergoes a second molt about 8 days after the first, or when she is about 20 days old, and 10 days later she is full-grown and within her transparent body (pl. 3, fig. 10) are seen partly developed young, which begin to appear in from three to 10 days later. Thus the round of life may be completed, as determined from a study of the

female, in from 33 to 40 days. The detailed studies made at Washington show that four full generations are developed normally in that latitude and that there may be a partial fifth. The production of a few young each day for some six weeks leads to a confusion of broods toward the end of the season, and their exact number can not be determined without special study. This insect breeds in the vicinity of Albany from the latter part of June through October. After making due allowance for the difference in latitude and the slower development in cooler weather, we can hardly expect more than three full generations normally, with a possibility of a fourth under exceptionally favorable conditions. This is confirmed by the studies of Prof. V. H. Lowe at Geneva. He found the average duration of the period of growth to be 49½ days, which gives just about time enough for three full generations during the growing season.

**Food plants.** This insect has been recorded on a considerable number of food plants, and its ability to live on so many varieties adds very much to the difficulty of exterminating or controlling it. The following is a list of food plants, as compiled by Dr Lintner, with a few additions by Dr Howard and from office records.

Tiliaceae
- Linden

Celastraceae
- Euonymus

Rosaceae
- Almond
- Peach
- Apricot
- Plum
- Cherry
- Spiraea
- Raspberry
- Rose
- Hawthorn
- Cotoneaster
- Pear
- Apple
- Quince
- Flowering quince

Saxifragaceae
- Gooseberry

Saxifragaceae (*continued*)
- Currant
- Flowering currant

Ebenaceae
- Persimmon

Leguminoseae
- Acacia

Oleaceae
- Lilac

Urticaceae
- Elm
- Osage orange

Juglandaceae
- English walnut
- Pecan

Betulaceae
- Alder ?

Salicaceae
- Weeping willow
- Laurel-leaved willow (from Asia)

The state of New York has for the last three years maintained a corps of inspectors for the purpose of examining all nursery stock for the presence of this and other injurious pests. Many exceedingly valuable facts have been gained in this manner, and the following comments on the food plants of the San José scale in New York state by G. G. Atwood, now in immediate charge of this work, are based on considerable experience. The plants are grouped in three sections.

1 This list of plants on which this scale is not found, although in proximity to infested plants, includes all evergreens and as follows, viz: ailanthus, althea, amaryllis, American ivy, anemone, aspen, azalea, barberry, Boston ivy, buckthorn, beech, butternut, buttonwood, catalpa, chestnut, cherry (black tartarian), chionanthus, clethra, corylus, currant (black), cranberry, deutzia, elder, elm (American), euonymus, exochorda, forsythia, ginkgo, hydrangea, Judas tree, halesia, hickory, Kentucky coffee tree, laburnum, larch, liquidambar, locust, magnolia, maples (sugar, Norway, ash leaf and Japan), matrimony vine, mulberry, oak, paeonia tree, philadelphus (mock orange), plum (wild goose), privet, rhododendron, silver thorn, snowball, spiraeas (some species), sycamore (plane tree), tamarix, tulip tree, viburnum, weigela, wistaria, xanthoceras and yellowwood.

2 The following is a list of plants on which the San José scale has been found, though in very small quantity, and no injury has resulted from its presence, and it is probable that it will not live over winter on them in this state, and it is not likely to breed freely on them: alder, amalanchier, ash, birch, blackberry, chestnut, dewberry, dogwood (flowering), elaeagnus, eucalyptus, fig, grape, honeysuckle, horse-chestnut, kerria, maples (silver and wiers), milkweed, mountain laurel, peppergrass, poplars (except aspen), quack grass, quince (edible), raspberry, rhus, spiraeas (some species), strawberries, walnut (English), and to this list I would add cherry commonly called "sour," including such varieties as Richmond, Morello, etc.

3 The following is a list of plants on which the San José scale finds suitable food, and therefore spreads rapidly, causing serious injury: acacia, akebia, apple, peach, pear, plum, cherry (sweet), apricot, nectarine, almond (flowering), cherry (flowering, Rocky mountain dwarf and Japan), cotoneaster, crataegus, currants (red, white and flowering), elm (English), gooseberry, Japan quince, mountain ash, peach (flowering), prunes (flowering and pissardi), Osage orange, snowberry and willow (many species).

It is noticed that this latter list is not very long, but unfortunately it includes the principal orchard trees and currants. In some sections it looks as if the San José would not thrive on Kieffer pears, while elsewhere it proves very destructive to this variety.

**Distribution.** This pest is widely distributed in the United States, having been recorded from 36 states and territories, besides the District of Columbia. It has also been found in a number of localities in Ontario (Can.)

This insect has gained a secure footing in New York state, as is shown by its having been found at one time or another in 29 of the 61 counties. The known infested localities are limited in many cases to one or two in a county. There has been no thorough survey of the bearing trees of the state; and, when that is made, many other infested orchards may be discovered, though it is hoped that such may not prove to be the case. It is quite important for the owner to know if his trees be infested with this pest; and therefore every fruit-grower is urged to send any twigs or fruit, which present a suspicious appearance, to an entomologist for examination.

**Original home.** There has been considerable written regarding this matter; and it now looks as if proof would shortly be forthcoming to show that this species is a native of Japan, a country considered by several who have given the subject attention, to be most probably its home. The evidence brought forward up to August 1899 failed to convince either Dr Howard or his colaborer, Dr Marlatt, that the pernicious or San José scale is a native of Japan, they holding that, so far as evidence is concerned, there was nothing to prove that the insect did not come to us from China, from some other portion of eastern Asia or possibly from some of the islands in the Pacific or from Australia. A recent note by Prof. V. L. Kellogg states that S. I. Kuwana, assistant in entomology at Stanford university, spent last summer in a systematic investigation of Japanese Coccidae and in the course of his work he found that the San José scale was distributed over the whole Japanese empire, it being in certain regions a serious pest. The note also states that Mr Kuwana "finds much evidence to uphold the belief that the insect is native to Japan." This announcement does not settle the question, but it looks as if Japan might prove to be the original home of the pest.

**Natural enemies.** A number of true parasites have been reared from this scale insect. Anaphes gracilis How. was obtained from infested twigs taken in Charles county (Md.) and Aspidiotiphagus citrinus Craw. was reared from the San José scale in California. Aphelinus mytilaspidis Le Baron and A. fuscipennis How. have been reared from scales taken in a number of localities in Maryland by Prof. W. G. Johnson. The latter species was bred in large numbers by Prof. Johnson and promises to become an important aid in controlling this pest.

A very small black lady bug, Pentilia misella Lec., an American species which feeds on the San José scale, was found by me in con-

siderable numbers in an infested orchard near Albany. The beetle, in its various stages, is represented in the accompanying figure. It is quite convex in shape and only $\frac{1}{16}$ of an inch long. The twice stabbed lady bug, Chilocorus bivulnerus Muls., is another native form known to feed on this pest. The beetle may be recognized by its jet black color relieved by two red spots on its wing covers. Several lady

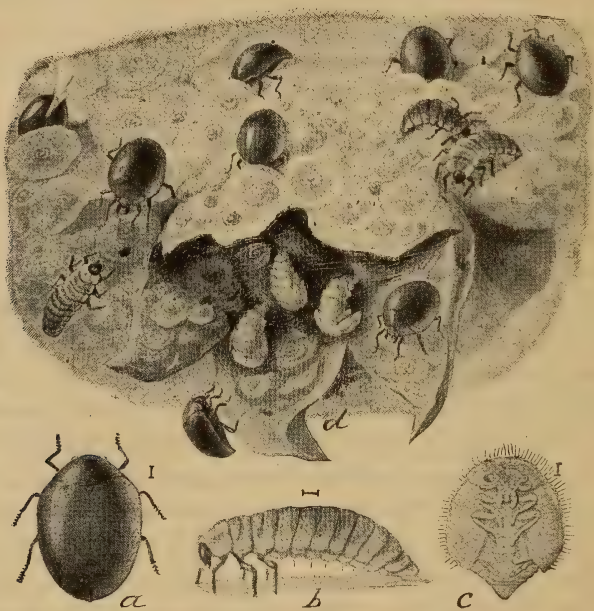


Fig. 5 Pentilia misella *a* beetle; *b* larva; *c* pupa; *d* blossom end of pear showing scales with larvae of Pentilia feeding on them, and pupae of Pentilia attached within the calyx—all greatly enlarged. (After Howard, U. S. dep't. agric. div. ent. Bul. 3, n. s. 1896)

bugs introduced into California were colonized on trees infested with San José scale, and of these, three have since been discovered feeding on the pest. They are Orcus chalybeus, O. australasiae and Scymnus lophanthae.

A fungus disease, Sphaerostilbe coccophila Tul., attacks this pest, and in some localities it has killed a considerable number of the scales. Prof. P. H. Rolfs credits this organism with practically exterminating the pernicious scale in one Florida orchard and with reducing by considerable the numbers of the pest in others. It is undoubtedly a native of Florida, as it is very common on Aspidiotus obscurus Comst. This fungus was cultivated, and new colonies of scales infested, but unfortunately, like other fungi it is very dependent on favorable

climatic conditions, and this limits its usefulness seriously. Fungus-infested scales were sent to other states, and the disease was at least temporarily established in several places. After the fungus has consumed the insect, an orange colored protuberance forms at the base of the scale or breaks through it, but, as this is only from $\frac{1}{40}$ to $\frac{1}{8}$ of an inch in hight, it is not very apparent.

**Necessity and value of certificates of inspection.** The present New York state law compels the inspection of all nursery stock by the commissioner of agriculture or his agents at least once a year prior to September 1; and, if the stock is found to be apparently free from dangerously injurious insects and from contagious diseases, the commissioner is required to issue a certificate stating the facts. A nursery found infested must be cleared of the scale before a certificate of freedom from pests can be granted. It is unlawful to ship any nursery stock by public carriers unless each car, box, bale or package be accompanied by such a certificate dated within a year. All transportation companies are now required by law to notify the state commissioner of agriculture whenever any nursery stock is received from any point without the state. This provision was made to aid in preventing the introduction of infested nursery stock from other states.

The value of a certificate depends much on the manner in which the inspection is conducted. That issued by our state department of agriculture represents faithful, close work, and it may be accepted as conclusive evidence that the trees are apparently free from this pest. Occasionally a few trees with the scale on them and accompanied by the commissioner's certificate have been received in other states; but I am not aware that any proof has ever been advanced to show that the infested trees were actually inspected in New York state, and in one or two instances it does not appear that the nursery stock was even sent from a point in this state. A certificate from a reliable party may be accepted as presumptive evidence of the freedom of the stock from this scale insect. It should not, however, prevent the buyer from scrutinizing the trees most closely and fumigating them, if they have not already been so treated.

**Means of dispersal.** These are limited, as pointed out in the general introduction, very largely to conveyance by other animals or by the elements. The young may crawl from tree to tree where branches interlock, they are blown some distance by prevailing winds, and the insect is also carried on young trees. Prof. Webster, in Ohio agricultural

experiment station bulletin 81, records an instance where this insect spread from an infested tree up a gully with the prevailing winds, while it made no progress in the opposite direction. This insect, in badly infested orchards, is frequently found in considerable numbers on the fruit, and in such cases the adult females may be producing numbers of young daily in the early fall. There is no record known to me of distribution of the San José scale by means of infested fruit, but such is a source of danger to adjacent orchards, where it may be carried or thrown by careless boys or men; and, if it is put on the market and sold in an uninfested locality, it may result in the introduction of the scale there. All that is necessary is that such fruit with bearing females be left close to a suitable food plant. This danger should be guarded against so far as practicable.

Careful investigations by the officials connected with the United States department of agriculture at Washington have shown that there is not the slightest danger of living San José scales being carried on dried fruits, as the drying is fatal to the insects.

**Preventives of attack.** The most effectual and in most cases the most practical method of preventing injury by this insect lies in excluding it from the orchard. There are even now localities in Long Island where the infestation of adjacent trees is bound to nullify any attempt to exclude this pest. Exclusion is possible, however, in most places in the state. A fruit-grower's first care should be to admit to his premises no trees or shrubs of any kind that may harbor this or other dangerous insects. The inspection of nurseries of New York state has done much to render difficult the sale of stock infested with this scale insect; but there is always a chance that some infested trees may be received by a dealer from outside, become mixed with that pronounced clean by the inspector and sold as such, and there is also a small possibility that once in a while a few infested trees may escape the inspector's eye. There have been several cases in this state where a very few of these scale insects must have lived on trees supposed to be clean for three to five years, at the end of which time it was suddenly found that they were badly infested with the pest. These facts are exceedingly strong arguments in favor of buying only stock that has been thoroughly fumigated by hydrocyanic acid gas, as this treatment is the best safeguard against the occasional scale insect.

Not only is it necessary to prevent the actual introduction of scale-intested stock in the orchard or on the farm, but the fruit-grower will soon

find it of advantage, so far as possible, so to locate his orchards as to reduce to a minimum the danger of this and other insect pests being conveyed by natural agents from adjacent orchards to his own. A man can never tell what pests a neighbor may unfortunately have in his orchard, or in a long series of years just how much care that orchard may receive. It is therefore good business to have valuable orchards somewhat isolated; and, if one man be fortunate enough to possess several, it would be well to have them somewhat separated and thus offer a serious obstacle to the spread of this or other pests from one orchard to another. A row of evergreen trees between adjacent orchards would probably prove of considerable service in preventing the carriage of scale and other insects from one orchard to another.

**Possibility of extermination.** There is no one at all familiar with the conditions, who expects to see New York state eventually freed from this pest. It is beyond the possibilities. The insect may be eradicated from certain places where it has not gained much of a foothold, but, as a general rule, it is very doubtful that the pest will be cleared from any locality where it has become even fairly established, because people will not ordinarily adopt the radical measures necessary to exterminate it. There are records of the insect having been exterminated from limited localities, but this line of work is advisable only where the infestation is comparatively recent, the area where the pest occurs sharply defined and distant from other infested trees or shrubs. Exclusion is the most promising method of protecting an orchard and next to that the adoption of methods for keeping the insect within moderate bounds. Because there has been difficulty in controlling this pest, it need not be assumed that such will always be the case. This insect is no longer greatly feared in certain parts of California, and the indications are most favorable for the finding of a practicable method of controlling the insect in the eastern United States.

**Method of extermination.** Dig up by the roots every infested tree and others at all likely to have this scale insect on them and burn them at once, unless this work be done in the late fall, when it may be advisable to allow the uprooted trees to lie in a pile till about June 1 before burning, in order to permit the escape of any beneficial parasites which may be present. Digging up by the roots is quite important because a few scale insects may be found on portions of the tree below the surface of the ground. A less radical method would be to destroy the infested trees as described above and to treat the suspected ones most thoroughly

in early spring with whale oil soap, mechanical petroleum emulsion or with hydrocyanic acid gas, the latter being the most efficient.

**Remedial measures.** These will be considered in detail under a separate head, special attention being given to the pernicious, or San José scale.

*Bibliography*

This scale insect has attracted more attention than any other injurious insect; and in these days of easy and rapid publication the notices regarding it have accumulated at a remarkable rate. The attention of the student is called particularly to the accounts and bibliographies by Dr Lintner, Dr Howard and his associate, Dr Marlatt, to which the appended bibliography is largely supplemental. A few of the most important notices cited by the above named writers have been repeated, and special attention has been given to the more important articles concerning this insect in New York state. No attempt has been made to include a mass of minor notices relating to this pest in other parts of the country or in other countries.

**Comstock, J. H.** U. S. dep't agric. Rep't of ent. 1880. 1881. p. 304–5 (original description).

**Lintner, J. A.** San José scale, Aspidiotus perniciosus and some other destructive scale insects of the state of New York. N.Y. state mus. Bul. 13. 1895. v. 3. p. 263–320 (general account of the scale with brief notices of other destructive species); Injurious and other insects of the state of New York. 11th rep't, 1895. 1896. p. 200–33, pl. 9–14 (the preceding reprinted with bibliography brought down to date); ——— 12th rep't. 1896. p. 316 (infested localities); San José scale. Country gentleman. July 8, 1897. 62 : 533 (general article).

**Howard, L. O. & Marlatt, C. L.** San José scale. U. S. dep't agric. div. ent. Bul. 3, n. s. 1896. p. 1–80. 1 pl. (a very full account of the insect); Original home of the San José scale. ——— Bul. 20, n. s. 1899. p. 36–39 (a critical examination of the evidence respecting its origin).

**Marlatt, C. L.** Insect control in California. U. S. dep't agric. Yearbook. 1896. p. 221–22 (parasites and resin wash); Temperature control of scale insects. ——— Bul. 20, n. s. 1899. p. 73–76 (effects of cold on various species); How to control the San José scale. ——— Circular 42. 2d ser. 1900. p. 1–6 (brief synopsis of remedies).

**Alwood, W. B.** Inspection and remedial treatment of San José scale. Va. agric. expt. sta. Bul. 79. 1897. p. 73–94 (account of

work done); San José scale question. Rural New Yorker. 1898. 57 : 127, 167 (proposed national legislation, value of inspection); State (Va.) inspector for the San José scale. 2d rep't. 1898–99. p. 1–34 (results and work of two years).

**Britton, W. E.** Insect notes of the season. Ct. agric. expt. sta. 21st rep't. 1897. p. 314–15 (brief notice); Entomological notes. ——— 22d rep't. 1898. p. 272–73 (results obtained with kerosene); San José scale in Connecticut. U. S. dep't agric. div. ent. Bul. 17, n. s. 1898. p. 81–84 (distribution and treatment); Inspection and care of nursery stock. Ct. agric. expt. sta. Bul. 129. 1899. p. 1–10 (general account with reference to local conditions).

**Lowe, V. H.** Inspection of nurseries and treatment of nursery stock. N. Y. agric. expt. sta. Bul. 136. 1897. p. 571–602 (treats of some other pests also but bears specially on this insect and methods of controlling it); Three important insects injurious to nursery stock. Western N. Y. hortic. soc. Proc. 1897. p. 71–74 (brief general account); Same in N. Y. state agric. soc. Trans. 1896. 1898 p. 654–58; Some investigations and experiments with the San José scale. Western N. Y. hortic. soc. Proc. 1901. p 36–47 (results obtained at Geneva).

**Rolfs, P. H.** Fungous disease of the San José scale. Fla. agric. expt. sta. Bul. 41. 1897. p. 513–44 (an account of Sphaerostilbe coccophila Tul. and its effects on the San José scale).

**Webster, F. M.** San José scale in Ohio. O. agric. expt. sta. Bul. 81. 1897. p 177–212 (general account with brief notices of other destructive scale insects); Importation of the San José scale from Japan. Can. ent. 1898. 30 : 169–72 (infested stock received from Japan, importation of parasites advised); Odour of San José scale. ——— 31 : 4 (notes odor of this scale); San José scale problem in Ohio in 1899. O. agric. expt. sta. Bul. 103. 1899. p. 185–99 (distribution in state, effects of insecticides); Some economic features of international entomology. Ent. soc. of Ont. 29th rep't, 1898. 1899. p. 30–31, 34 (legislation relating to San José scale) p. 104 (odor); Native home of the San José scale. ——— 30th rep't, 1899. 1900. p. 55, 56 (Japan probably the original home).

**Bogue, E. E.** San José scale in Oklahoma. Okl. agric. expt. sta. Bul. 34. 1898. p. 1–8 (brief, general account).

**Cockerell, T. D. A.** San José scale. Entomological news. 1898. p. 95 96 (Japan probably original home); Kieffer pear and the San José

scale. Science. Sep. 28, 1900. p. 488–89 (note on resistance of this variety to scale attack).

**Cooley, R. A.** Notes on some Massachusetts Coccidae. U. S. dep't agric. div. ent. Bul. 17, n. s. 1898. p. 63–64 (additional infested localities).

**Felt, E. P.** Two bad insects. Country gentleman. 1898. 63:206 (distribution in state); Certain destructive scale insects. ——— 63:453–54 (brief general account); Nursery and orchard inspection. ——— 63:586 (suggestions for guidance of inspectors); Everlasting San José scale. ——— 63:993 (fruit and plants from United States excluded by certain countries); Notes on some of the insects of the year in the state of New York. U. S. dep't agric. div. ent. Bul. 17, n. s. 1898. p. 22–23 (injuries, distribution, etc.); Injurious and other insects of the state of New York. 14th rep't, N. Y. state mus. Bul. 23. 1898. v. 5. p. 154, 240–42 (same); Controlling insect pests. Country gentleman. 1899. 64:767 (repressive measures of value); Illustrated descriptive catalogue of some of the more important injurious and beneficial insects of New York state. N. Y. state mus. Bul. 37. 1900. v. 8. p. 12–13 (brief description and remedies); Remedies for San José scale. Country gentleman. 1900. 65 965 (results obtained with kerosene, crude petroleum, whale oil soap and hydrocyanic acid gas); Some effects of early spring applications of insecticides on fruit trees. U. S. dep't agric. div. ent. Bul. 26 n s. 1900. p. 22–25 (results obtained with crude petroleum); Scale on Japan plum. American gardening. 1900. 21:811 (treatment) Insect lessons of the year. Country gentleman. 1901. 66:192 (summary of experiments against San José scale); Injurious and other insects of the state of New York. 16th rep't. N. Y. state mus. Bul. 36. 1901. v 7 p. 967–88 (details of experiments with insecticides); N. Y. state agric. soc. Trans. 1899. 1901. p. 280–82, 284 (brief notice); Recent problems in the control of insects depredating on fruit trees. Mass. fruit growers ass'n. Rep't. 1901. p. 38–45 (injuries, remedial measures).

**Gillette, C. P.** Colorado's worst insect pests and their remedies. Col. agric. expt. sta. Bul. 47. 1898. p. 14–15 (brief notice).

**Gould, H. P.** Notes on spraying and on the San José scale. Cornell univ. agric. expt. sta. Bul. 144. 1898. p. 575–92 (spraying and its effect on this pest); 2d rep't on the San José scale with remarks on the effects of kerosene on the foliage. ——— Bul. 155. 1898. p. 159–71 (results of experiments).

**Hallock, Nicholas.** San José scale on Long Island. Rural New Yorker. 1898. 57 : 688 (infested fruit shown at fair).

**Howard, L. O.** San José scale in 1896–97. U. S. dep't agric. div. ent. Bul. 12, n. s. 1898. p. 1–32 (history of the insect 1896–97, bibliography brought down to date); Recent laws against injurious insects in North America. ——— Bul. 13, n. s. 1898. p. 1–68 (compilation of laws, many of which relate to the San José scale); San José scale on dried fruit. ——— Bul. 18, n. s. 1898. p. 7–13 (experiments proving that living scales can not exist on dried fruit); Regulations of foreign governments regarding importation of American plants, trees and fruits. ——— Circular 41. 2d ser. 1900. p. 1–4 (brief synopsis of rules).

**Hopkins, A. D.** Some notes on observations in West Virginia. U. S. dep't agric. div. ent. Bul. 18, n. s. 1898. p. 44–45 (effects of kerosene).

**Johnson, W. G.** Hydrocyanic acid gas as a remedy for the San José scale. U. S. dep't of agric. div. ent. Bul. 17, n. s 1898. p. 39–43 (results of experiments); Report on the San José scale in Maryland, and remedies for its suppression and control. Md. agric. expt. sta. Bul. 57. 1898. p. 1–116 (an exhaustive account); Notes on the external characteristics of the San José scale, cherry scale and Putnam's scale. Can. ent. 1898. 30 : 82–83 (grosser characteristics); Nursery fumigation and the construction and management of the fumigating house. Pa. dep't agric. Bul. 56. 1899. p. 1–24 (directions for fumigation); Miscellaneous entomological notes. U. S. dep't agric div. ent. Bul. 20, n. s. 1899. p. 66 (new infested localities found, effects of cold weather); Some physiological effects of hydrocyanic acid gas upon plants. Sci. American, suppl. no. 1249. Dec. 1899. p. 20,026–27 (details of effects on various trees and shrubs); Aphelinus fuscipennis an important parasite of the San José scale in the eastern United States. U. S. dep't agric. div. ent. Bul. 26, n. s. 1900. p. 73–74 (observations on parasites); Use of hydrocyanic acid gas. Rural New Yorker. 1900. 59 : 1–2, 33, 65, 82–83 (application and methods); Fumigating nursery trees. ——— 59 : 495 (summary account); Points about winter spraying. American agriculturist. 1900. 66 : 677–78 (directions for winter work); Fumigation of nursery stock. ——— 1901. 67 : 236–38 (directions for fumigating); Effects of gas on nursery stock. ——— 67 : 362 (gives amounts different kinds of nursery stock will stand); Important enemy of the San José scale. ——— 67 : 398 (notice of Aphelinus fusci-

pennis); Emory fumigator for fruit trees. ——— 67 : 432 (description and use); More about fumigation. ——— 67 : 470 (additional notes).

**Kirkland, A. H.** San José scale in Massachusetts. Mass. bd agric. Bul. 2, ser. 1898. p. 24–38 (general account); same in Rep't. 1898. p. 295–315.

**Page, F. H.** Test and treatment for San José scale. Rural New Yorker. 1898. 57 : 218 (experience with several insecticides).

**Pettit, R. H.** Some insects of the year 1897. Mich. agric. expt. sta. Bul. 160. 1898. p. 410–13 (brief account).

**Sanderson, E. D.** Attacking the San José scale. Country gentleman. 1898. 63 : 753–54 (abstract of Prof. Johnson's report).

**Slingerland, M. V.** Dip for the San José scale. Rural New Yorker. 1898. 57 : 180–81 (treatment of infested nursery stock); Cold and San José scale. ——— 1899. 58 : 544 (scale resistant to cold in the north); Western N. Y. hortic. soc. Proc. 1900. p. 51 (firmly established in New York); Eastern N. Y. hortic. soc. Proc. 1900. p. 57 (widely distributed in state); San José scale on pears. Rural New Yorker. 1900. 59 : 672 (badly infested trees should be destroyed); Crude petroleum for San José scale. ——— 59 : 733 (results in Hudson valley).

**Symposium.** Spreading the San José scale. Rural New Yorker. 1898. 57 : 17–18 (articles on value of certificates, etc. by several entomologists and horticulturists).

**Smith, J. B.** Distribution of the San José, or pernicious scale in New Jersey. U. S. dep't agric. div. ent. Bul. 17, n. s. 1898. p. 32–39 (record of distribution and observations); Regulating the San José scale by law. Rural New Yorker. 1898. 57 : 341, 373, 383–84 (conditions in New Jersey, value of certificates); San José scale at home. ——— 1899. 58 : 597 (remedies); N. J. agric. expt. sta. Rep't. 1898. p. 396–447 (records and results obtained with insecticides in experimental orchard, natural enemies, distribution); ——— Rep't. 1899. p. 434–35, 456–512 (distribution, results in experimental orchard, remedies, notes, etc.); Crude petroleum as an insecticide. ——— Bul. 138. 1899. p. 1–22 (results of experiments on trees infested with San José scale); Rep't of state ent. N. J. state bd of agric. 26th rep't, 1898. 1899. p. 69–89 (summary of work against San José scale, conditions, etc.); Three common orchard scales. N. J. agric. expt. sta.

Bul. 140. 1899. p. 7–16 (general account); San José scale and other insects. Rural New Yorker. 1900. 59:686–87 (natural enemies, remedies); Rep't of state ent. N. J. state bd of agric. 27th rep't, 1899. 1900. p. 23–28 (summary of work for the year); Crude petroleum versus the San José or pernicious scale. N. J. agric. expt. sta. Bul. 146. 1900. p. 1–20 (results obtained with crude oil, general discussion of the subject); San José scale and crude petroleum. Rural New Yorker. 1901. 60:121–22 (summary of results); N. J. agric. expt. sta. Rep't, 1900. 1901. p. 508–48 (experiments with crude petroleum).

**Stedman, J. M.** San José scale in Missouri. Mo. agric. expt. sta. Bul. 41. 1898. p. 15–35 (general account).

**Taft, L. R. & Trine, D. W.** Legislation relating to insects and diseases of fruit trees, and preliminary report of the state inspector of nurseries and orchards. Mich. agric. expt. sta. Bul. 156. 1898. p. 311–20 (digest and text of law with list of licensed nurserymen).

**Aldrich, J. M.** San José scale in Idaho. Univ. of Idaho agric. expt. sta. Bul. 16. 1899. p. 1–16 (life history and conditions in the state).

**Beach, S. A., Lowe, V. H. & Stewart, F. C.** Common diseases and insects injurious to fruits. N. Y. agric. expt. sta. Bul. 170. 1899. p. 428–29 (description, treatment).

**Carnochan, James.** San José scale. Rural New Yorker. 1899. 58:495 (conditions in Canada).

**Collingwood, H. W.** How Maryland fights San José scale. Rural New Yorker. 1899. 58:259, 277–78, 299 (general account of methods in vogue in that state).

**Fernald, H. T.** San José scale, and other scale insects. Pa. dep't agric. Bul. 43. 1899. p. 5–16 (general account).

**Fletcher, James.** Injurious insects in 1898. Ent. soc. of Ont. 29th rep't, 1898. 1899. p. 86 (notes on work against); Injurious insects in Ontario during 1899. ——— 30th rep't, 1899. 1900. p. 106 (note on conditions in Canada).

**Forbes, S. A.** Recent work on the San José scale in Illinois. Univ. of Ill. agric. expt. sta. Bul. 56. 1899. p. 241–87 (present condition of state and results of experiments); Ill. state ent. Report concerning operations under the horticultural inspection act. 1900. p. 1–30 (review of the work of the year against the San José scale).

**Hunter, S. J.** Coccidae of Kansas. Kan. univ. quarterly. 1899. 8 : 10–11 (technical characters).

**Kelsey, F. W.** San José scale scare. Country gentleman. 1899. 64 : 917 (scare overdone).

**Newell, Wilmon.** On the North American species of the subgenera Diaspidiotus and Hemiberlesia of the genus Aspidiotus. Ia. state coll. of agric. and mechanic arts. Contributions from the dep't of zoology and entomology. no. 3. 1899. p. 16–17 (description, distribution, affinities) ; Some injurious scale insects. Ia. agric. expt. sta. Bul. 43. 1899. p. 163–65.

**Scott, W. M.** Fatal temperature for some Coccids in Georgia. U. S. dep't agric. div. ent. Bul. 20, n. s. 1899. p. 82–84 (scales killed in southern Georgia by freezing).

**Sirrine, F. A.** Report of committee on insects. Eastern N. Y. hortic. soc. Ap.–Jl. 1899. p. 2 (brief account of local conditions).

**Troop, James.** San José and other scale insects and the Indiana nursery inspection law. Ind. agric. expt. sta. Bul. 78. 1899. p. 45–52 (brief account of this and other scale insects and the text of the law).

**Waugh, F. A.** San José scale. Country gentleman. 1899. 64 : 853 (summary of situation).

**Atwood, G. G.** Food plants of the San José scale. Country gentleman. 1900. 65 : 885 (food plants).

**Beach, S. A.** Fumigation of nursery stock. N. Y. agric. expt. sta. Bul. 174. 1900. p. 1–8 (directions for fumigation) ; San José scale question from a horticultural standpoint. Western N. Y. hortic. soc. Proc. 1900. p. 19–24 (brief résumé of the situation) ; San José scale in New York. Rural New Yorker. 1900. 59 : 155 (abstract of general paper ; *see* preceding).

**Bethune, C. J. S.** Some recent work in economic entomology. Royal soc. of Can. Trans. v. 6, § 4, separate. p. 3–9 (résumé of work in Canada).

**Card, F. W.** San José scale in Rhode Island. Country gentleman. 1900. 65 : 829 (well scattered over state).

**Corbett, L. C.** W. Va. agric. expt. sta. Bul. 70. 1900. p. 365–76 (experiments with crude oil and other insecticides).

**Davis, G.** Petroleum as an insecticide. Rural New Yorker. 1900. 59 : 542 (75% of treated trees killed).

**Kellogg, V. L.** Stanford university's collection of Japanese scale insects. Psyche. 1900. 9:144 (San José scale probably native of Japan, as it is well distributed over that empire).

**Lochhead, William.** San José and other scale insects. Ont. dep't agric. Toronto. Mar. 1900. p. 1–48 (general account with brief notices of other destructive scale insects).

**Lyman, H. H.** President's annual address. Ent. soc. of Ont. 30th rep't, 1899. 1900. p. 26–27 (résumé of situation in Canada).

**Reh, L.** Scale insects on American fruit imported into Germany. [English abstract] U. S. dep't agric. div. ent. Bul. 22, n. s. 1900. p. 79–83 (mature females render importation very possible).

**Wiley, H. S.** Fumigation of nursery stock. Rural New Yorker. 1900. 59:235 (demand for fumigation).

**Willard, S. D.** San José scale legislation. Western N. Y. hortic. soc. Proc. 1899. p. 125–27 (rep't of committee, discussion); San José scale. 1900. p. 90–96 (report of committee on legislation followed by an extended discussion).

**Woodward, J. S.** Why oppose the San José scale law? Rural New Yorker. 1900. 59:183 (urges support of proposed fumigation amendment); Conference on the San José scale. Ent. soc. of Ont. 30th rep't, 1899. 1900. p. 3–20, 57 (details of a conference held at London (Ont.) Oct. 11, in which a number of entomologists and other interested persons took part).

## European fruit scale insect

*Aspidiotus ostreaeformis* Curtis

PLATE 4

This species has been in New York state probably much longer than the pernicious, or San José scale and yet it is a comparatively unknown insect to farmers and fruit-growers. This form was first received at the United States department of agriculture in 1895 from Dr Peter Collier, then director of the experiment station at Geneva. It was erroneously referred to one of the allied species, no one at the time suspecting its foreign origin. The systematic inspection of nurseries in the state, begun in 1898, resulted in finding much more of this scale insect. G. G. Atwood, then of Geneva, and a nursery inspector, had the fullest oppor-

tunity for learning of the distribution of this species. The original infestation was probably in an orchard in Geneva propagated from cuttings imported some 30 years ago. All other places in the state, so far as was ascertained by Mr Atwood, had received buds or cuttings from this orchard. So it seems most probable that this insect has been established in the state about 30 years.

**A European pest.** This species is stated by Dr Marlatt to be a well-known pest on various fruit trees in Europe. He is of the opinion that, were it as actively exploited in this country as has been its close relative, the pernicious or San José scale, it would assume a similar importance. It is undoubtedly a species which should be carefully watched, but its behavior in the state of New York up to the present does not justify the expectation that it will ever in this latitude rank in importance with the closely allied Aspidiotus perniciosus. Mr Atwood in a letter dated Ap. 4, 1899, states that in no case was serious injury evident. I have received some pieces of bark pretty badly infested with this species, but the average shows fewer insects than is the case with trees infested with the pernicious scale insect. This form seems to be more injurious in Pennsylvania, as some nursery stock badly infested with this species has been received from there.

**Description.** The general appearance of this species is similar to that of the pernicious, or San José scale. The white stage is shown in figure 1. A quite characteristic appearance of the young of this species is shown natural size in figure 2 and enlarged in figure 3. The sides of the scale are dark gray, while the center which is nearly white, may be grayish or brown. The young appear to have quite a habit of arranging themselves at nearly equal distances from one another. The white or brown portion of the adult scale may break away and expose the yellowish cast skin or exuviae, as is shown in figures 4 and 5. A number of scales are represented natural size in figure 6 and a portion enlarged in figure 7. Some of the young are always found among a mass of old scales, and, when they are white, the gray of the old scales is lightened considerably. Sometimes masses of this scale insect are a dark gray, and then the young are usually grayish or brownish. The individual adult female scale may attain a diameter of nearly $\frac{1}{8}$ inch. It has a yellowish or orange nipple a little to one side of the center, and the gray part of the scale is normally marked with black specks (*see* fig. 9), and, when on a rough tree, the edge of the scale is usually continuous with the outer layer of the bark. The male scale (fig. 8) is somewhat oval in outline.

The female insect as removed from under a scale is represented in fig. 10, and one of her yellowish progeny in fig. 11.

**Life history.** The winter is passed by partly grown individuals which become mature toward the last of June. This insect, like the pernicious scale, is ovoviviparous, that is, gives birth to living young, which begin to appear about the last of the month and continue to emerge for several weeks. This species produces but one generation in this latitude, and this restriction alone makes it much less dangerous than the preceding form.

**Food plants.** This insect appears to have a decided preference for plum in New York state, since it is most frequently found on this fruit tree. It has also been found on apple, pear, cherry, prune, currant, purple-leaved plum, mountain ash, elm, linden, Carolina poplar and willow.

**Distribution.** This insect has become established in widely separated localities in America. It has been reported from the following states: Ohio, Michigan, Iowa, Idaho, Kansas, and it has been received from Pennsylvania. Dr Marlatt records its presence at several Ontario (Can.) localities, and in British Columbia.

This species is now widely distributed in the state, having been received from Fredonia, Chautauqua co., Lewiston and Youngstown, Niagara co., Brighton, Penfield and Rochester, Monroe co., Geneva and Stanley, Ontario co., Williamson, Wayne co., near Kinderhook, Columbia co. and Millbrook, Dutchess co. It has been received by Dr Howard from Trumansburg, Tompkins co., Grooms, Saratoga co., Troy, Rensselaer co., Fishkill, Dutchess co. and Blauvelt, Rockland co.

**Remedies.** Methods of value against the pernicious or San José scale should prove equally effective with this species, and as a rule it will probably be found much easier to control.

*Bibliography*

The following records are confined almost entirely to the American history of this species.

**Curtis, John.** Gardener's chronicle. 1843. p. 830 (original description).

**Lintner, J. A.** Injurious and other insects of the state of New York. 11th rep't, 1895. 1896. p. 271 (on apple).

**Marlatt, C. L.** A dangerous European scale insect not hitherto reported but already well established in this country. Science. July 7,

1899. 10:18–20 (record of introduction, distribution, food plants); An account of Aspidiotus ostreaeformis. U. S. dep't agric. div. ent. Bul. 20, n. s. 1899. p. 76–82 (detailed account).

**Newell, Wilmon.** On the North American species of the subgenera Diaspidiotus and Hemiberlesia, of the genus Aspidiotus. Ia. state coll. of agric. and mechanic arts. Contributions from the dep't of zoology and entomology. no. 3. 1899. p. 10 (form described as A. hunteri) p. 17–18 (synonymy, description).

**Parrott, P. J.** Kan. state hortic. soc. Trans. 1898. 1899. p. 108 (mention).

**Felt, E. P.** Injurious and other insects of the state of New York. 15th rep't. N. Y. state mus. Bul. 31. 1900. v. 6. p. 617–18 (localities and food plants noted during the year); Illustrated descriptive catalogue of some of the more important injurious and beneficial insects of New York state. ——— Bul. 37. 1900. v. 8. p. 13 (characteristics and remedies).

**Lochhead, William.** San José and other scale insects. Ont. dep't agric. 1900. Toronto. p. 33–35 (brief account of it in Canada).

**Pettit, R. H.** Some insects of the year 1899. Mich. agric. expt. sta. Bul. 180. 1900. p. 120–24 (brief general account).

## Putnam's scale insect

*Aspidiotus ancylus* Putnam

PLATE 5

This is the most common native species of Aspidiotus found on fruit trees and shrubs in New York state. Occasionally it may occur in such large numbers as to be somewhat destructive, but ordinarily natural agents of one kind or another keep it in check. Mr Cooley records a case in Massachusetts where nearly every tree in a young apple orchard was infested, some abundantly, and one was dying from the attacks of this species. This record is very exceptional, at least for New York state, though I have seen it very abundant on currant.

**Description.** This species is of importance largely because of the liability of its being mistaken for the much more dangerous, pernicious, or San José scale. It is distinguished with difficulty by external characters from the preceding species. A twig badly infested with Putnam's scale has a dark gray or almost black color relieved here and there by the reddish, eccentric larval skins or exuviae. There are few or none of

the whitish remnants of young scales, as frequently seen in the European fruit scale before the insects are disturbed by abrasion of any kind. The young scales of this species may be almost white or pinkish, as shown in figures 1–4, their edges are sharply defined, the dot and ring are present, but there is rarely the oval, white nipple surrounded by a grayish, specked scale almost continuous with the bark, as in the European fruit scale; neither are the young as dark, nor as flattened as are those of the pernicious scale. The half-grown young have the appearance represented in figure 5. The adult female scales, which are about $\frac{1}{12}$ inch in diameter, are shown natural size in a mass in figure 6 and more enlarged in figure 7, which latter also represents a rather characteristic shape of this scale when it occurs in masses. Figure 9 illustrates a female scale as it may develop when comparatively isolated. A rather irregular male scale is represented in figure 8. The adult female and the active young are shown very much enlarged in figures 10 and 11.

**Life history.** This insect, like the preceding, passes the winter in a partly grown, though usually more mature, condition. There is but a single generation. The studies of Mr Putnam, in Iowa, show that the males appear there the latter part of April, and that the female deposits from 30 to 40 eggs in the late spring or early summer. The crawling young of this species may be seen during most of July, in the latitude of Albany, indicating that the hatching of the eggs extends over a considerable period. Prof. Johnson states that this species may cause a purplish tinge in green tissue, but it is not so marked as with the San José scale. I have not observed this discoloration in New York state.

**Food plants.** This species has been recorded on a number of plants. Prof. Comstock has found it on ash, beech, bladdernut, hackberry, linden, maple, oak, Osage orange, peach, and water locust. Dr Lintner has received it on apple and red currant—on the latter it is sometimes very abundant, and he has also seen it on olive, evidently from a greenhouse at Jamaica (L. I.) It has also been recorded on cherry, plum, elm and willow. Prof. Johnson attributes the killing of an English oak in Illinois to this scale insect. It has been received from this state by Dr Howard on pin oak and hemlock. It also occurs on mountain ash, pear, nectarine, *Ilex verticillata*, *Ilex laevigata*, white birch, *Prunus*, American elm and on hawthorn in West Virginia.

**Distribution.** This insect has been recorded from the following states, Kansas, Iowa, Michigan, and New York, and from Washington (D. C.) R. A. Cooley found it to be one of the most common species in

Massachusetts, which is also true of it in this state. That it is one of our commonest species of Aspidiotus on fruit trees is shown by its being the most numerous of those found by Dr Reh on fruit imported into Germany from America (*see* Bibliography). It has been received from the following localities, a portion of which were kindly communicated by Dr Howard: Palmyra, Wayne co., Brighton, Monroe co., Medina, Orleans co., Geneva and Stanley, Ontario co., Waterloo, Seneca co., Ithaca, Tompkins co., Benton, Yates co., Germantown, Columbia co., Ellenville, Ulster co., Glen Cove, Nassau co., Blauvelt, Rockland co., Flushing, Far Rockaway and Jamaica, Queens co., and Brooklyn. It occurs commonly about Albany.

**Natural enemies.** A minute chalcid parasite, Coccophagus varicornis How., was reared from this species by Prof. Comstock.

**Remedies.** This insect can be checked, when necessary, by spraying with the insecticides and in the manner recommended for the San José scale.

*Bibliography*

**Putnam, J. D.** Ia. state hortic. soc. Trans. 1877. 1878. 12: 321 (original description, as Diaspis); Davenport acad. of natural sciences. Proc. 1877. 2: 346–47 (notes on life history, synonymy).

**Comstock, J. H.** U. S. dep't agric. Rep't of ent. 1880. 1881. p. 292–93 (synonymy, description); Cornell univ. expt. sta. dep't ent. 2d rep't. 1883. p. 58–59 (synonymy, food plants).

**Packard, A. S.** U. S. ent. com. 5th rep't. 1890. p. 482, 520, 553–54 (on linden, beech and ash; Comstock's description quoted).

**Lintner, J. A.** Bad scale on currant bushes. Gardening. May 15, 1895. 3: 263 (on currant); Injurious and other insects of New York. 11th rep't, 1895. 1896. p. 213, 271, 275, 287 (mention, on apple and red currant).

**Lugger, Otto.** Minn. state expt. sta. 1st rep't ent. 1895. 1896. p. 129–30 (on elm).

**Cockerell, T. D. A.** N. M. agric. expt. sta. Bul. 19. 1896. p. 104, 106, 107 (mention, on apricot and plum); The San José scale and its nearest allies. U. S. dep't agric. div. ent. Technical ser. 1897. no. 6. p. 5, 7, 8, 9, 17, 20 (technical characters, affinities).

**Johnson, W. G.** Notes on new and old scale insects. U. S. dep't agric. div. ent. Bul. 6, n. s. 1896. p. 76 (on English oak); Notes on the external character of the San José scale, cherry scale and Putnam's scale. Can. ent. 1898. 30: 82–83 (superficial characters).

**Gillette, C. P.** A few insect enemies of the orchard. Col. agric. expt. sta. Bul. 38. 1897. p. 36–37 (brief notice); Colorado's worst insect pests and their remedies. ——— Bul. 47. 1898. p. 15 (mention).

**Lowe, V. H.** N. Y. agric. expt. sta. Bul. 136. 1897. p. 593 (mention, food plants); ——— 15th rep't, 1896. 1897. p. 533 (brief notice).

**Aldrich, J. M.** Report of the dep't of ent. Id. agric. expt. sta. Bul. 15. 1898. p. 175–76 (brief notice).

**Forbes, S. A.** Noxious and beneficial insects of Illinois. 20th rep't of state ent. 1895–96. 1898. p. 15, 16, 17 (economic importance, characteristics).

**Cooley, R. A.** Notes on some Massachusetts Coccidae. U. S. dep't agric. div. ent. Bul. 17, n. s. 1898. p. 64 (common in Massachusetts).

**Felt, E. P.** Injurious and other insects of the state of New York. 14th rep't. N. Y. state mus. Bul. 23. 1898. v. 5. p. 261 (localities and food plants noted during the year); ——— 15th rep't, 1899. ——— Bul. 31. 1900. v. 6. p. 579 (mention), p. 617 (localities and food plants noted during the year); Illustrated descriptive catalogue of some of the more important injurious and beneficial insects of New York state. ——— Bul. 37. 1900. v. 8. p. 13 (characteristics, remedies).

**Pettit, R. H.** Mich. agric. expt. sta. Bul. 160. 1898. p. 414 (brief notice).

**Hunter, S. J.** Coccidae of Kansas. Kan. univ. quarterly. Jan. 1899. 8: 4 (critical notes, food plants).

**King, G. B.** Contributions to the knowledge of Massachusetts Coccidae. Can. ent. 1899. 31: 226 (distribution in state, food plants).

**Marlatt, C. L.** Aspidiotus convexus, Comst. A correction. Can. ent. 1899. 31: 209–11 (A. convexus, a synonym in part).

**Newell, Wilmon.** On the North American species of the subgenera. Diaspidiotus and Hemiberlesia, of the genus Aspidiotus. Ia. state coll. of agric. and mechanic arts. Contributions from the dep't of zoology and entomology. 1899. no. 3, p. 7–10 (description of species and varieties); some injurious scale insects. Ia. agric. coll. expt. sta. Bul. 43. 1899. p. 160–62 (brief technical account).

**Parrott, P. J.** Some scales of the orchard. Kan. hortic. soc. Trans. 1898. 1899. p. 108 (brief notice).

**Lochhead, William.** San José and other scale insects. Ont. dep't agric. Toronto. 1900. p. 37–38 (typical form not in Ontario, brief notice).

**Reh, L.** Scale insects on American fruit imported into Germany [English abstracts] U. S. dep't agric. div. ent. Bul. 22, n. s. 1900. p. 79, 80 (common on fruit, but immature).

## Cherry scale insect

*Aspidiotus forbesi* Johnson

PLATE 6

This species is the rarest in New York state of those noticed in detail in this bulletin. It has been known to science but five years, having been described by Prof. W. G. Johnson in 1896.

**Previous history.** Prof. Johnson characterized this species as the most dangerous scale insect then established in Illinois. It was first discovered on Morello cherry, and later he found that it was generally distributed over the state. It also occurred on wild cherry, and, on account of its apparent partiality for that tree, the above common name was proposed. Prof. Johnson states that it was not uncommon in 1896 to find seven and eight year old cherry trees literally covered with the pest, and that a number were killed by it. Prof. Forbes, state entomologist of Illinois, writing of this and allied species in 1898, states that "they are of no extraordinary interest to the fruit growers, none of them being either as abundant or as destructive when present as the commonest of the native orchard scales, the so called scurfy scale of the apple, Chionaspis furfura". It will probably prove no more injurious in this state than in Illinois.

**Description.** This scale insect is closely allied to the three preceding forms. Its rarity in the state has prevented a thorough study of its external characteristics. A mass of the adult scales, so far as observed by me, is much lighter in color than that of either of the two preceding species and usually lighter than a similar mass of San José scale, because the latter is almost sure to include a number of the dark gray or nearly black young. The general appearance of an infested twig is shown in figure 6, and a group from this is enlarged in figure 7. The adult female scales are rather flat, yellowish gray, and about $\frac{1}{12}$ inch in diameter and with a reddish, eccentric larval skin or exuviae. The color and general appearance is well shown in figure 7 and in greater detail in figure 8,

which represents the scale of a fully developed female. The form and orange red exuviae of the male scales are illustrated in figure 9. The varying appearance of the young is shown in figures 3, 4 and 5.

**Life history.** This species, as determined by Prof. Johnson, winters partly grown in Illinois, the males appearing about the middle of April and the young beginning to emerge early in May, eggs and young being found as late as June 20. This insect, in the latitude of Springfield (Ill.) produces two generations annually, the males of the second brood appearing from July 10 to August 1, and the young of this generation from the first week in August till late in September.

**Distribution.** Prof. Johnson states that this insect is common in Illinois and neighboring states. It is apparently very rare in New York state, having been received from Manchester, Cornwall and Kinderhook and by Dr Howard from Geneva. So far as known, it has been found in but two localities in Massachusetts. Prof. Hunter records it from Kansas and New Mexico. It also occurs in Maryland, Georgia and West Virginia.

**Natural enemies.** The following seven parasites were reared by Prof. Johnson from this scale insect: Prospalta murtfeldti How., Prospalta aurantii How., Perrisopterus pulchellus How., Signiphora nigrita How. MS., Arrhenophagus chionaspidis Aur., Ablerus clisiocampae Ashm., and a species belonging to the genus Encyrtus. He also observed whitish mites under the scales. The twice stabbed lady bug, Chilocorus bivulnerus Muls., in both adult and larval stages, feeds on this insect.

**Food plants.** This insect has been recorded on the following: apple, apricot, cherry, pear, plum, quince, currant and honey locust.

**Remedies.** Thorough spraying with insecticides, as recommended for the San José scale, should prove equally effective with this species.

*Bibliography*

**Johnson, W. G.** Descriptions of five new species of scale insects, with notes. Ill. state laboratory of natural hist. v. 4. art. 13. 1896. p. 380–83 (original description); Notes on new and old scale insects. U. S. dep't agric. div. ent. Bul. 6, n. s. 1896. p. 74–75 (notes on life history, food plants, habits and parasites); Preliminary notes on five new species of scale insects. Ent. news. 1896. 7 : 151 (notes); Notes on some little known insects of economic importance. U. S. dep't agric.

div. ent. Bul. 9, n. s. 1897. p. 85 (widely distributed); Notes on the external characters of the San José scale, cherry scale and Putnam's scale. Can. ent. 1898. 30: 82–83.

**Lintner, J. A.** Injurious and other insects of New York. 11th rep't, 1895. 1896. p. 271 (on apple).

**Cockerell, T. D. A.** San José scale and its nearest allies. U. S. dep't agric. div. ent. Technical ser. no. 6. 1897. p. 5, 7, 9, 16, 17, 21 (technical characters, affinities).

**Cooley, R. A.** Notes on some Massachusetts Coccidae. U. S. dep't agric. div. ent. Bul. 17, n. s. 1898. p. 64 (found in Massachusetts).

**Forbes, S. A.** Noxious and beneficial insects of the state of Illinois. 20th rep't state ent. 1895–96. 1898. p. 15, 16, 17 (economic importance, characteristics).

**Hopkins, A. D.** Some notes on observations in West Virginia. U. S. dep't agric. div. ent. Bul. 17, n. s. 1898. p. 45 (widely distributed in state).

**Hunter, S. J.** Scale insects injurious to orchards. Univ. of Kansas, dep't ent. Bulletin. 1898. p. 24–25 (brief account); Coccidae of Kansas. Kan. univ. quarterly. Jan. 1899. 8: 3–4 (critical notes, food plants).

**Newell, Wilmon.** On the North American species of the subgenera Diaspidiotus and Hemiberlesia of the genus Aspidiotus. Ia. state coll. of agric. and mechanic arts. Contributions from the dep't of zoology and entomology. 1899. no. 3. p. 14–16 (description and distribution); Some injurious scale insects. Ia. agric. coll. expt. sta. Bul. 43. 1899. p. 162 (technical characters).

**King, G. B.** Contributions to the knowledge of Massachusetts Coccidae. Can. ent. 1899. 31: 226 (distribution in state, food plants).

**Parrott, P. J.** Some scales of the orchard. Kan. state hortic. soc. Trans. 1898. 1899. p. 108–9 (widely distributed).

**Popenoe, E. A.** Some insects of the year. Kan. state hortic. soc. Trans. 1898. 1899. p. 42–43 (general account).

**Lochhead, William.** San José and other scale insects. Ont. dep't agric. Toronto. 1900. p. 35–37 (brief general account).

**Reh, L.** Scale insects on American fruit imported into Germany. [English abstract] U. S. dep't agric. div. ent. Bul. 22, n. s. 1900. p. 79, 80 (but few specimens found).

## White scale insect of the ivy

*Aspidiotus hederae* Vallot

PLATE 7

This species is rather common in greenhouses in the state, and not infrequently it causes considerable damage, specially to ivy, its favorite food plant. The ivy is not always killed, but the white scales on the dark green leaves render it unsalable. Large quantities of this foliage plant have been rendered worthless in this manner.

**Description.** Infested plants may be recognized by the white, irregular patches of scale insects. An examination of one of these under a lens will show it to be composed of a number of yellowish-white, circular scales, each with a deeper yellow cast skin, or exuviae, a little to one side of the center. The appearance of an infested spray of ivy is well shown in figure 7. The large, yellowish-white scales are usually surrounded by a number of small white ones. Such a group is represented much enlarged in figure 6, and a full-grown female scale, which is about $\frac{1}{12}$ inch in diameter, more enlarged in figure 4, while a young white scale is shown very greatly enlarged in figure 3. Some of the yellowish, active young can usually be found on an infested leaf. One is shown much enlarged in figure 2. The removal of an adult scale may uncover a yellowish female, represented in figure 1, or there may be found only her shriveled remains, shown greatly magnified in figure 5, and possibly a few very minute yellowish eggs and one or two active young (fig. 8).

**Life history.** The conditions in the greenhouse usually permit this insect to breed continuously, so that there is no demarcation of broods. Adult females, half-grown individuals and crawling young can usually be found at almost any time. This insect lives outdoors in the southern states, and, under these conditions, Prof. Comstock is of the opinion that there are at least two generations annually. He bred adult males in April from specimens received both from California and Florida, but I have been unable to find a sign of this sex on a badly infested ivy plant kept under observation for some months. This species is apparently both oviparous and ovoviviparous. I have observed eggs and living young besides empty egg shells under female scales, and Mr Coquillett states that he has witnessed the birth of living young.

**Distribution.** This is a well-known European species which has a wide distribution, having been recorded from such distant places as Australia, Chile and Cuba. It has attained a general distribution in the

United States. It is known to be present in a number of widely separated localities in New York state, and it will probably be found in greater or less numbers wherever greenhouse plants have been grown for some years.

**Food plants.** This pest is able to subsist on a number of different plants. Prof. Comstock has studied it on acacia, magnolia, oleander, maple, yucca, plum, cherry, currant and the china-tree, Melia azedarach, in California and on ivy at Ithaca (N. Y.) He also found it on grass and clover growing in pots with infested trees and on lemons from the Mediterranean and from California. Prof. Morgan states that it is very abundant on the "china-tree" in Louisiana. It is recorded as a pest of the olive in countries where that tree grows. Prof. Johnson states that it is particularly destructive in Maryland to Asparagus plumosus, the so-called lace fern. D. W. Coquillett records it in California on the following additional plants: lilac, arbor vitae, century plant or aloe, oak, Quercus agrifolia, and nightshade, Solanum douglasii. It has also been collected in Albany greenhouses on Areca lutescens, Cyperus, Kentia belmoreana and Strelitzia reginae.

**Natural enemies.** Prof. Morgan reports rearing a hymenopterous parasite from this scale insect, and Mr Coquillett states that the imported Australian lady bug, Rhizobius debilis Blackb., feeds on this species in California.

**Preventives and remedies.** It is comparatively easy to control this insect in New York state, since it can not live outdoors. It can be kept in check by spraying or washing the infested plants with whale oil soap solution (1 pound to about 5 gallons), kerosene emulsion (diluted with 12 parts of water, *see* p. 339) or an ivory soap solution (a 5 cent cake of the latter to 8 gallons of water). These substances will hardly do more than keep this insect in check, and repeated applications will be necessary. It will be much more satisfactory, as a rule, to clean the greenhouse thoroughly in the summer and then stock up with clean plants.

*Bibliography*

The more important articles treating of this species in America are listed below. No attempt has been made to look up references in foreign publications, as the list, at best, would be very incomplete.

**Signoret, Victor.** Essai sur les Cochenilles ou Gallinsectes. 1868. p. 96–97 (description) 100–3 (food plants, description, as A. nerii).

**Comstock, J. H.** U. S. dep't agric. Rep't of ent. 1880. 1881. p. 301–3 (description, life history and habits); Cornell univ. expt. sta. dep't ent. 2d rep't. 1883. p. 10 (brief notice, both as A. nerii).

**Osborn, Herbert.** Entomological notes for the year 1882. Ia. state hortic. soc. Trans. 1882. 1883. 17:213 (a serious greenhouse pest, as A. nerii).

**Lintner, J. A.** Scale insect attack on ivy. Country gentleman. 1885. 50:169 (brief notice, giving remedies); same in Rep't state entomologist to the regents of the University of the State of New York. 1885. p. 113–14; Injurious and other insects of the state of New York. 5th rep't, 1888. 1889. p. 278–79 (brief general account); —— 8th rep't, 1891. 1893. p. 214–15 (on oleander); San José scale, Aspidiotus perniciosus, and some other destructive scale insects of the state of New York. N. Y. state mus. Bul. 13. 1895. v.3. p. 271–72 (brief notice); Injurious and other insects of the state of New York. 11th rep't, 1895. 1896. p. 203–4 (all as A. nerii).

**Harvey, F. L.** Me. agric. expt. sta. Rep't, 1888. 1889. p. 184–85 (on ivy, remedy, as A. nerii).

**Riley, C. V. & Howard, L. O.** Insects introduced into Chili. Insect life. 1888. 1:154 (acclimated); —— 1890. 2:252 (identification); —— 1892. 4:347 (established in America); —— 1893. 6:59 (in Australia); —— 1894. 6:327 (A. nerii possibly a synonym of A. hederae, all preceding as A. nerii).

**Coquillett, D. W.** Report on the scale insects of California. U. S. dep't agric. div. ent. Bul. 26. 1892. p. 20–21 (food plants, notes as A. nerii); Present status of recent Australian importations. Insect life. 1893. 6:29 (Rhizobius debilis feeding on A. nerii).

**Morgan, H. A.** Scale insects of the orange. La. agric. expt. sta. Special bul. 1893. p. 75–77 (on china-tree, description); Rep't of the ent. —— Bul. 28. 1894. p. 996 (on lemons, both as A. nerii).

**Cockerell, T. D. A.** Aspidiotus nerii. Ent. news. 1894. 5:79 (notes on food plants and distribution); San José scale and its nearest allies U. S. dep't agric. div. ent. Technical ser. no. 6. 1897. p. 18, 30 (characters, food plants, latter as A. nerii).

**Johnson, W. G.** Notes on new and old scale insects. U. S. dep't agric. div. ent. Bul. 6, n. s. 1896. p. 76 (destructive to Asparagus plumosus, as A. nerii).

**Hunter, S. J.** Coccidae of Kansas. Kan. univ. quarterly. Jan. 1899. 8 : 11–12 (critical notes).

**King, G. B.** Two new coccids from Bermuda. Psyche. 8 : 350 (in Massachusetts greenhouses); Bibliography of Massachusetts Coccidae. Can. ent. 1900. 32 : 12 (same); Coccidae of the ivy. —— 1900. 32 : 214–15 (list of species, synonymy).

## Remedial measures against armored scale insects

The recommendations on the following pages are based very largely on experiences with the pernicious, or San José scale, and in a number of cases they are advised only for that insect. Measures found effective against this pest can hardly fail to give satisfactory results when used under similar conditions against the other species treated. The experience of the last few years has demonstrated that in certain sections of this state nothing but continuous fighting will prevent serious damage to orchards infested by the pernicious, or San José scale.

**Only contact insecticides of value.** It hardly seems necessary to dwell on this subject. It is quite well understood that scale insects draw their sustenance from the underlying plant tissues through a slender proboscis or haustellum. This method of feeding renders it impossible to kill the pests by using paris green or other stomach or internal poisons. The only way to get at these creatures is to apply to them some substance which will kill by contact, and even this, in the case of the armored scales and some others, is difficult on account of the protective covering which may shield the insect to a considerable extent. There are plenty of substances which will kill these pests, but the difficulty is to find something which will not at the same time injure the tree. The cost of material and its effect on the apparatus employed must also be considered.

**Whale oil soap.** The winter or early spring treatment for the pernicious, or San José scale appears to be the most effectual and satisfactory. The infested trees should first of all be trimmed back severely. This not only economizes in the amount of material necessary, but renders it possible to give more effectual treatment. Thorough spraying with a potash whale oil soap solution, using 2 pounds to a gallon of water and applying it just before the buds open, will check this pest severely and will not injure the trees. This treatment is perfectly safe, and, if thoroughly carried out, quite satisfactory, but, judging from our experience, it can not be relied on to kill all the scales. It should prove equally effective against the allied species of Aspidiotus. It is

quite essential to have a potash soap that does not contain more than 30% of water. Such a soap can be secured in large quantities at from 3½c to 4c a pound, thus making the mixture cost 7 to 8c a gallon. Soda soaps are difficult to apply in winter on account of the solution being gelatinous when cold. Experiments with both Good's and Leggett's whale oil soaps gave little or no difference in their insecticidal value. Good's soap dissolved much easier and was less difficult to spray.

**Whale oil soap and crude petroleum combination.** Experiments with a combination of whale oil soap and crude petroleum, did not give as good results as were obtained with a plain 20% crude petroleum emulsion. This compound was obtained by dissolving a pound of whale oil soap in each 4 gallons of water and putting the mixture in the barrel of a "kerowater" sprayer.[1] Crude petroleum was placed in a tank and the pump set to deliver 10% oil, thus obtaining a whale oil, petroleum emulsion.

**Crude petroleum emulsion.** Treatment of the pernicious or San José scale in early spring with a 20% mechanical emulsion of crude petroleum, using a "kerowater" sprayer, was found even more satisfactory than the whale oil soap solutions, and so far it appears not to have injured the trees in the slightest degree. The petroleum used was the blended product sold by the Standard oil co. as crude petroleum. It is said to run about 44° on the Beaumé oil scale, but a sample of the oil used gave a reading of but 37° while some purchased in December 1900 stood at 41.5°. It was tested in 1900 both in an experimental and in a practical way with most excellent results. There is less danger of injuring the trees if a lighter oil is used and it is apparently just as effective as an insecticide. W. H. Hart of Poughkeepsie (N. Y.) obtained most excellent results on a large scale with a mechanical dilution of crude petroleum purchased of the Frank oil co., Titusville (Pa.). This oil runs from a little above 43° to nearly 45° on the Beaumé oil scale. The mechanical emulsion does not change the nature of the oil, but it enables the operator to cover a tree thoroughly with a minimum amount, and thus there is not only a saving of material but there is less danger of injuring the tree The crude petroleum spreads readily, adheres to the bark in spite of repeated rains, leaving a glossy coat of the heavier oils, which remains

[1]Made by the Gould manufacturing co., Senaca Falls N. Y. Mechanical sprayers are also made by other manufacturers. It is well to test them when working from time to time by turning the spray into a jar, allowing the oil and water to separate and then to measure the amounts of each.

moist and distinctly visible for several months, and this residuum undoubtedly interferes with the establishment of young scale insects. The spraying should be done when the bark is dry. It must be very thorough, and, in places where the scales have formed incrustations, it is quite difficult to kill all the insects even with this substance. The best method in a large orchard is to spray at two different times, working always on the windward of the trees and spraying the second half when the wind is from the opposite direction to that from which it was when the first half was sprayed. A 10 foot brass extension with two to four cyclone nozzles is almost necessary for the best results. W. H. Hart, of Poughkeepsie, prefers to have the nozzles connected with the extension by a small piece of pipe bent at an angle of about 45° from the line of the extension. Some prefer the nozzles set at a right angle to the extension. It is better to have them turned somewhat, and the precise angle is apt to vary with individual preferences. Trees sprayed with crude petroleum or kerosene should not be trimmed previous to the application as the cuts afford an opportunity for the oil to enter and kill the twig for a short distance. Experiments with this mechanical emulsion on the allied species of Aspidiotus are advised.

**Crude petroleum undiluted.** Experiments with this undiluted crude oil showed it to be very injurious to plant life, killing two out of four trees and seriously injuring the others. The effects of an application of this undiluted crude petroleum to plumtrees is strikingly shown on plate 8. The lombard plumtree 93 was sprayed with this substance April 11. Compare its appearance on July 2 with that of tree 8, one of the same variety, which was sprayed April 11 with a 20% mechanical kerosene emulsion. A little later in the season tree 93 died. Plate 9 shows the effect of crude petroleum on seckel peartree 101. Note the dead limbs and contrast this with the illustration of the Kieffer peartree 110, which was sprayed on the same date as the others but with Good's whale oil soap no. 3. It is a pleasure to record that this latter tree fulfilled the promise of its bloom. The photograph taken at Kinderhook May 21 of a King appletree, which was painted with crude petroleum Dec. 1, 1899, apparently shows that this substance is more deadly if the application be made in early winter. This tree died during the summer. At present the use of the undiluted article can not be recommended as safe in New York state. Dr Smith states in a recent bulletin that he has found that crude petroleum which ran above 43° on the Beaumé oil scale did not injure the trees, that below 40° was liable to cause serious injury, while the oil giving a reading of

35° was almost uniformly fatal. A safe petroleum, he states, must be either a green or an amber colored paraffin oil, not an asphaltum oil. There is still need of more experiments along this line and of a clearer understanding of just what is meant by crude oil before the use of undiluted petroleum can be advised in this state.

**Kerosene.** Spraying trees in early spring with ordinary undiluted kerosene did not result in nearly so thorough work as a 20% crude petroleum emulsion, and it was much more injurious to the trees. Its use can not be advised.

**Kerosene emulsion.** A mechanical 10% kerosene emulsion is a most excellent summer spray to be applied when the young scale insects are numerous, and it has proved harmless to the trees. H. P. Gould has used a 20% mechanical emulsion in summer without harming the trees to an appreciable extent, but as the lower per cent of oil gives very satisfactory results, there is no necessity of using more. Early June applications would probably prove very effective against appletree and scurfy bark lice. The 20% and 25% mechanical emulsions applied in early spring just before the buds started, failed to kill many scale insects, and its use is not recommended at this time.

**Other summer sprays.** The ordinary kerosene emulsion may be prepared by taking 1½ pounds of hard soap, 1 gallon of boiling water and 2 gallons of kerosene. Dissolve the soap in the water, add the kerosene and then agitate the mixture vigorously by stirring or by repeatedly passing it through a force pump with a nozzle attached, till an emulsion of creamy consistency is obtained, and oil does not rise to the surface. For summer work against the San José scale this may be diluted with 9 parts of water. 1 pound of whale oil soap dissolved in 5 gallons of water may be used in a similar manner without injury to the trees. The sour milk emulsion, which is simply 2 gallons of kerosene and 1 gallon of sour milk, emulsified and diluted as described above, is preferable for limestone regions or where soft water can not be obtained readily. These summer sprays are of service only in checking the San José scale, if previous applications have for some reason proven unsatisfactory. They are very efficient when used against appletree and scurfy bark lice.

**Fumigation in orchards.** Treatment of pernicious, or San José scale with hydrocyanic acid gas gave most excellent results on small trees in an orchard. Unfortunately it involves the use of costly tents, specially for large trees. It is admirably adapted for large orchards of

small trees, and, where such are reasonably distant from other infested trees, an attempt might be made to exterminate the pernicious scale by fumigation. A box tent 6x6 and 8 feet high, with a hood 7 feet high and a sod cloth some 6 inches wide, was made of 8 ounce duck which was thoroughly painted with boiled linseed oil. Rings for guy ropes were provided at the upper corners, and the tent was lifted by a rope attached to the extremity of the hood. The form of the tent was kept rather constant by using a light frame composed of four side pieces and slender posts at each corner (*see* pl. 10). The tent was handled with the aid of a 35 foot mast and an 8 foot gaff and tackling, and was raised bodily and dropped over the tree. The mast could be fixed to a heavy wagon when used on level ground where the trees are some distance apart. This tent and outfit cost $38, but, as only one was made, much better terms could be secured if several were ordered. The cost of treatment, aside from apparatus, is comparatively little. The secret of doing this work economically consists in having enough tents, so that the men will not have to wait but will be kept busy changing one after another. A little experience will enable those handling the tent to raise it from one tree, swing it over another, lower it, fix it in position, place the chemicals and have the fumigation started within a short time. Five to 10 or more tents could be used in a large orchard to advantage. The economical use of a small number of tents would necessitate some employment near at hand to occupy spare minutes. Dormant trees can be fumigated in this latitude, even when the sun shines, without any apparent injury to the trees. The gas should be allowed to act for 35 minutes or a little longer, and 1 ounce of potassium cyanid (98% pure) to each 75 cubic feet of space, with an equal amount by liquid measure of the best grade of commercial sulfuric acid (specific gravity 1.83) and thrice that amount of water, did not appear to injure the trees in the least, while every scale insect was apparently killed. The above amounts for 100 cubic feet of space gave equally good results. A better proportion, according to Prof. Johnson, is 1 ounce cyanid, 1½ ounces acid and 2¼ ounces water. The cyanid and acid are both very dangerous substances, and should be handled with the greatest care. The cyanid should be conspicuously labeled, kept in a tight, covered can and not taken therefrom till it is to be used. The sulfuric acid is capable of producing horrible burns, and it should be guarded most carefully. The acid should be turned into the water slowly, the mixture being constantly stirred. A glazed earthenware crock is one of the best vessels for the chemicals, and it should be placed under the tent near its middle but not close to the trunk of the tree.

Sometimes the acid spatters a little during the reaction, and this precaution is to prevent injury either to the tree or to the tent. If the tent is already over the tree, look to see that it is properly secured and all of the sod cloth covered, except on the windward side where the chemicals are to be inserted. Then take the cyanid, previously weighed out and placed in a thin paper bag, reach under the tent, carefully drop it into the acid and water and at once draw down the side of the tent and cover the remainder of the sod cloth. The contents of the earthenware vessel, after the tent has been removed, should be carefully buried near the tree. Take special pains to see that none of it comes in contact with a tent. Some preliminary figuring and a little experience will soon make one quite expert in estimating the contents of a box tent above described. Other forms of tents are in use, but the above is probably the best for young trees, though it can not be handled well in a stiff breeze. A bell-shaped tent with its lower edge attached to a large hoop is used considerably in California, and this can be handled in treating small trees without the aid of a mast. The sheet tent, which is nothing more than a square of properly treated canvas of sufficient size, is also much used in that state, specially on large trees.

**Fumigation of nursery stock.** The mere possibility of the introduction of the San José scale or some other insect pest should be a sufficient reason for the careful fruit-grower to prefer fumigated stock, and the advisability of this treatment in the case of trees open to the slightest suspicion of harboring such an insect is conceded by every careful fruit-grower and nurseryman. The methods of doing this are essentially the same as those mentioned above for orchard fumigation except that it is much more convenient to treat nursery stock in a special building or room, and allowance must be made for the more tender varieties. The essentials of a fumigating chamber are that it must be gas-tight, easily closed and opened from the outside, readily ventilated and so arranged that there will be no difficulty in placing the chemicals where a practically uniform distribution of the gas will be insured. A slat floor, eight or more inches from the ground, under which the gas may be generated, is a decided advantage as it gives a more uniform distribution of the insecticide. The room may be only a few feet square or large enough to contain a load of trees on a wagon, according to the needs of the firm or individual. Small lots of trees can be fumigated in a box, but as a rule this is not advisable. The materials necessary to make a gas-tight house, as worked out by

Prof. W. G. Johnson in Maryland, are substantially as follows: A good frame, covered outside with $1\frac{1}{4}$x12 inch Virginia pine boards and $1\frac{1}{2}$x4 inch batting. The interior, including the floor, was lined with two-ply cyclone paper, over which four inch flooring was laid. The doors should be made double, refrigerator style, hung with heavy hinges and with bolts at top and bottom and a lock in the middle. There should be a second opening either on the side or roof so as to permit ready ventilation. Trees fumigated in a freight car are very liable to serious injury, and it should not be attempted. A second fumigation should be avoided as the trees may be much damaged. A small room about 4x5x7 is exceedingly convenient, even when there is a large one, as it economizes chemicals in the fumigation of small lots of trees.

The cubic contents of a room should be carefully calculated and the necessary chemicals measured out. Ordinary dormant nursery stock will stand $1\frac{1}{8}$ ounces (avoirdupois) of potassium cyanid (98% pure) to 100 cubic feet of space, according to Mr Sirrine, while for immature stock, bud sticks, etc. but $\frac{5}{8}$ ounce should be used. Prof. Sirrine recommends the following proportion: $1\frac{1}{8}$ ounces cyanid, $1\frac{3}{8}$–$1\frac{1}{2}$ fluid ounces sulfuric acid and $4\frac{1}{2}$ fluid ounces water for matured stock, and $\frac{5}{8}$ ounce cyanid, $\frac{3}{4}$ fluid ounce acid and $2\frac{1}{2}$ fluid ounces water for immature stock. Allow the gas to act from 40 to 60 minutes. I have obtained very satisfactory results with the formula given under orchard fumigation; but this latter is undoubtedly good and possibly more economical. Trees in leaf or those with buds started can not be fumigated with safety. The cost of fumigating nursery stock is very slight. One man constructed a house large enough to accommodate 8000 trees of first class size at an expense not to exceed $30. A person with considerable experience in this line finds that trees can be fumigated in quantity at less than $\frac{1}{4}$c apiece.

Great care should be exercised in this work as well as when treating orchard trees. Special pains should be taken to air the fumigating room thoroughly before allowing any person to enter. The doors should be open at least 10 minutes. This gas is very deadly, nearly odorless and too much care can not be exercised.

# TECHNICAL STUDY OF FOUR SPECIES OF ASPIDIOTUS

BY MARGARET FURSMAN BOYNTON

## PREFACE

The four species of Aspidiotus, A. ancylus, A. forbesi, A. ostreaeformis and A. perniciosus, are those most commonly found on fruit trees in New York state. They are closely related, and all pass the winter as immature individuals. Much of the inspection of nursery stock is done either in the fall or in the early spring, and it frequently happens that we are called on to identify a species from immature specimens. It is very true that adults should be somewhere in the vicinity of the young, but, as a matter of fact, it is frequently difficult to obtain a satisfactory amount of adult material for study; consequently it is quite important that we be able to separate these species by characters found in immature as well as adult specimens. A study of these species, with directions to give special attention to the immature stages, was assigned to my second assistant, Miss Boynton. The results are given in the following paper.

E. P. FELT

**Explanation of terms.** In the study of scale insects the final appeal for the determination of species is, of course, to the microscopic detail of the anal plate, made up of the terminal segments, of the adult female. Here peculiar organs appear which are designated by distinctive names, and must be recognized by the terms so used in order to understand any technical description of species. It may be well to illustrate with a diagram (pl. 11) and to explain those which occur in the following characterizations, specially as the usage of these terms varies somewhat with different writers.

The margin of the anal plate is irregular, usually showing broad and somewhat thickened prolongations of the body wall. These are called lobes (pl. 11, fig. 1*a*). In the following species there are two or four, paired bilaterally, as are most of the important organs on this segment, and some times there are the rudiments of a third pair. It is supposed that they are used in shifting the position of the insect under the scale. Spines and plates also ornament the margin. The spines appear under the microscope like short, stiff hairs with bulbous bases. They are likely to extend more or less nearly at right angles to the general line of the margin, are similarly arranged on the two sides of the median line, and are usually on the two surfaces, the dorsal and the ventral. That is, when the focus is fixed

on the spine of one surface, a spine of the other surface may usually be detected close by, though somewhat out of focus (pl. 11, fig. 1 *b*, *b*). This fact will be taken for granted in the following description, and no farther mention of it will be made.

The plates, which are called also gland hairs, or, by Green, squames, extend, in general, nearly parallel to the main axis of the body, and appear soft and for the most part clearer and broader than the spines, and lack the bulbous base, but they assume various forms and may be either simple and hair-like, or forked or fringed at the tip. Varying outlines are shown in figure 1 at *c*, *c*, *c*, *c*. They are often hard to detect definitely, as they are transparent and sometimes disappear in clearing, either through actual dissolution or by attaining the same refractive index as the mounting medium. Their function is probably connected with the excretion of the scale.

The margin is often cut in or incised. In the following species two pairs of incisions can usually be detected, the second being comparatively inconspicuous (pl. 11, fig. 1 *d*, *d*).

Beside the incisions are heavily chitinized places which appear dark in the cleared specimens. These have been spoken of by Prof. Comstock as the "thickened margin of the incisions," but by later writers are more frequently termed "chitinous processes"; and this phrase I shall use, applying it also to the thickenings which sometimes appear on the inner margins of the median lobes. These last have been spoken of as "club-shaped processes"; but, as this term has also been applied to other organs, it seems wiser to discard it, simply giving definiteness to the term "chitinous processes" by some phrase of location. Different forms of these processes are shown in plate 11, figure 1 *e*, *e*, *e*, *e*. A general thickening of the body wall inward from the lobes frequently occurs, but is usually rather indefinite in appearance (fig. 1*f*).

As the insect is so much flattened, there are practically but two aspects, the dorsal and the ventral. In a well cleared specimen the organs of both sides are visible at once, yet by careful focusing can be distinguished. In plate 11, figure 1, the superficial organs of the ventral side are represented in the left half of the figure; those of the dorsal side on the right. Perhaps the most important of these superficial organs are those which appear on the ventral side of the body as groups of distinct circular organs with several tiny perforations in the middle of each. They are the openings of glands which presumably secrete the covering of the eggs, and have been variously named the spinnerets, the paragenital glands, the circumgenital glands and the ventral grouped glands. I shall

speak of them simply as the ventral glands. They appear only in the adult female and not in all species. They are of rather special interest in economic study because their presence at once proves the specimen to be something other than the pernicious or San José scale, though their absence does not necessarily indicate the contrary. Once seen they are easily recognized, for no other organ resembles them in their definite circular outline and in the manner of grouping (pl. 11, fig. 1 *g*, *g*). In the genus Aspidiotus there are usually four or five groups when present at all. The groups are then spoken of as the anterior or cephalo-laterals, and the posterior, or caudo-laterals, while the fifth group when present is anterior and median and is called by the one or the other of these terms.

In the region of the lateral ventral glands the body wall is thickened (pl. 11, fig. 1*h*). These are the ventral chitinous thickenings, and are to a certain degree characteristic. In A. ancylus and A. ostreaeformis they are somewhat indefinite and appear as if folded or crumpled, in A. forbesi they are nearly straight, narrow and definite, being spoken of in the original description as "club-shaped organs about which the spinnerets are grouped." In A. perniciosus also they are more definite than in A. ancylus and A. ostreaeformis, though not so straight nor so narrow as in A. forbesi, and they appear distinct and dark in the adult female even when the eggs or young are not present to prove the species. This distinguishes the adult but not yet gravid A. perniciosus from the immature specimens of the four species, because in the first and second stages of all four these thickenings, though indicated, are small and indefinite, practically *parenthesis-shaped* and quite different from the third stage appearance. Reference to the figures will make these statements perfectly clear, I think.

The vagina may sometimes be detected as a tranverse opening about the middle of the plate on the ventral side (pl. 11, fig. 1*j*). It does not in general serve in classification, and I have not figured it under the different species.

The dorsal aspect is marked near the base of the segment in the following species by four, transverse chitinous thickenings, two lateral and two median (pl. 11, fig. 1 *k*, *k*). Occasionally there are two fainter longitudinal markings of chitin parallel and near the middle of the segment.

There are also on the dorsal aspect oval openings of more or less prominence in different species, which are perhaps most simply designated the dorsal pores. I have shown different appearances of these seen in focusing in plate 11, figure 1 *l*, *l*. In some species they are numerous and

prominent, in others not nearly so much so. They are perhaps openings of glands which assist in the formation of the scale. Among these are seen curious organs which may seem to be on the surface of the body but are proved by focusing to occur within it in connection with external openings. These have been denominated by Prof. Comstock the wax ducts. In the explanatory figure a few are represented at *m*, *m*, but not in later figures, as they have not been shown to have definiteness of arrangement or classificatory value.

The large circular opening on the dorsal side is the anus (pl. 11, fig. 1*n*). Like the other dorsal organs it is visible from the ventral side also, appearing as a clear area.

I think no other organs of importance are present in the four species here mentioned. There are sometimes visible a few minute round pores and some small superficial spines, or hairs, but they may be disregarded.

**Distinguishing species.** It is of course a commonplace in many divisions of science, but perhaps in none more than in the study of the Coccidae, that familiarity with forms is necessary for any great degree of certainty in determining species. Descriptions of two or three different species read marvelously alike, and even figures are not absolutely distinctive, because of the great variability in species. Moreover, the untrained eye does not quickly recognize differences, specially where distinctions must be largely comparative. Hence any key to species must in the nature of things be unsatisfactory, for it must be relative in its terms and so can not be used with large degree of certainty in each step till familiarity with the species renders it unnecessary. However, it is sometimes an aid in earlier studies through its emphasis of the more distinctive features, and the following is submitted with that end in view. It applies only to the four species here farther characterized, and perhaps may not exclude other species, which have not fallen under my ken, so that it will be useful only when the student finds it probable that he has one of these four, but is not sure which one. They are the four species of Aspidiotus most frequently brought to the attention of horticulturists in this state, a fact which may justify this limitation of my study.

This key will apply, I think, to the second stages as well as to the mature females, though with hardly as much positiveness. I have been unable to detect constant specific differences in forms before the first molt. Sometimes the question may arise as to whether the form presented is adult or not. This occurs when neither ventral glands nor eggs nor young are present. In this case if the ventral thickenings are

definite and well marked and of considerable size, the specimen is a third stage, female A. perniciosus, though not yet gravid. The second stage of these four species shows only the vague, somewhat parenthesis-shaped thickenings mentioned above and seen in the second stage illustrations. Of course the third stage of the other three species is marked by the ventral glands even before the young appear within the body. In addition, the occasional difficulty in detecting the arrangement of the plates must always be remembered.

## Key

A Incisions wide and not very deep. Second pair of lobes small when present. Median lobes rather broad.

B With fringing plates. Second pair of lobes rudimentary or wanting . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . A. ancylus

BB Plates inconspicuous or wanting. Second pair of lobes usually distinct, though small . . . . . . . . . . . . . . . . A. ostreaeformis

AA Incisions narrow. Lobes distinctly two pairs, of good size. Median lobes rather narrow.

B Lobes nearly parallel. Fringing plates. Thickenings on either side of the first incision subequal. No ventral glands even in gravid female . . . . . . . . . . . . . . . . . . . . . . . . . . A. perniciosus

BB Lobes usually strongly approximating at tips. Plates inconspicuous or wanting. Thickenings on either side of first incisions distinctly unequal. Ventral glands present in adult. A. forbesi

## Aspidiotus forbesi *Johns*

PLATES 12 AND 13, FIGURES 1

This species appears to approach A. perniciosus most closely in general outline. (Compare each figure with the second figure of the same plate, A. perniciosus.) It has four distinct lobes: the median ones are notched on the outer margins and approximate at the tips, the second ones are about half the size of the first and usually notched on the outer margin. They also slant slightly inward, giving the species in general a decidedly pigeon-toed appearance. The lobes are close together, because the incisions (two pairs) are narrow. The first incisions are quite deep. The second are not so much so. Prof. Johnson in the original description and figure located four spines on each side of the median line; these are quite prominent. There is a fifth pair often visible near the union of the terminal and the penultimate segments. In general the spines do not

differ from the allied species. The plates when present are few and small; occasionally one or two may be detected between or beside the lobes.

The chitinous processes are very characteristic, though hard to describe. The tips of the lobes are quite heavily chitinized, and the processes extending cephalad along the inner margins of the median lobes are usually comparatively large and distinct. Newell, in his Iowa bulletin no. 43, p. 161, speaks of these as sharp pointed and curved in contradistinction to the almost straight ones of A. ancylus. This difference, if constant, takes very careful focusing to determine, and is not striking, as is proven by the fact that other illustrators of the species have not brought it out. Indeed, the original figure represents these processes as straight and quite different in shape from Newell's figure. This point is probably good additional evidence of the identity of the species when it can be definitely ascertained, but is not the most obvious and easiest criterion. There is also an extension of chitin cephalad near the outer margin of the median lobes.

The chitinous processes on the inner margin of the first incision are large, much larger than those opposite. They are almost pear-shaped with a compound curve on the side toward the median line. That is, they are often abruptly narrowed toward the tip and outer margin of the lobe with a full curve to the very broad and plump cephalic part. This may seem a hazy description till somewhat cleared by study of the figures and by familiarity with the forms. As a matter of fact these chitinous processes are quite distinctive in A. forbesi being easily distinguished from the more indefinite and irregular ones of A. ostreaeformis and A. ancylus and somewhat less certainly from A. perniciosus by the narrower distal part, and specially by the usually marked superiority in size to the opposite process, while in A. perniciosus the two processes are subequal. The chitinous processes about the small second incision vary more than in the case of the first incision.

The adult female shows ventral glands in 5 groups. Johnson gives 1–3 for the anterior group, 3–7 for the anterior laterals and 3–5 for the posterior laterals. The general arrangement of these is somewhat linear.

The ventral chitinous thickenings within the posterior lateral groups are nearly straight and club-shaped and are usually narrow and definite, as stated above. Sometimes a fainter, less heavily chitinized fold or fork appears, but the main and obvious process is more or less nearly as illustrated and is usually in line with a small, straight, more heavily chitinized portion of the general thickening inward from the base of the lobes mentioned in the paragraph for the explanation of terms.

On the dorsal side the anus is easily detected. The dorsal pores are small and clean-cut and usually run in two rows, on either side of the median line, one from the second incision toward the lateral transverse chitinous thickening and the second row laterad of that and running clear to the outer end of the same thickening, one pore usually being against the thickening. The number of these pores is variable but I have several times counted six or eight in each row. At the first incision there are two or three pores.

The second stage of A. forbesi (pl. 13, fig. 1) resembles the third in general, though, of course, it is smaller in size. At this stage, the second lobes seem somewhat smaller comparatively and are more often rounded than notched. The characteristic approximation at the tips usually occurs, and aids in distinguishing this form from the second stage of A. perniciosus which usually shows nearly parallel lobes. The chitinous processes are usually of the characteristic shape, but sometimes are not so marked in disparity of size as in the adult. The spines and plates are as in the adult. The ventral glands are of course wanting, and the ventral thickenings are faint and indefinite, as in the others of these four species. The dorsal pores are fewer than in the adult but represent in scattering lines the arrangement of the later stage. Quite often one may be observed even beyond the lateral chitinous thickenings.

## Aspidiotus perniciosus *Comst.*

PLATES 12 AND 13, FIGURES 2

The adult female of the pernicious or San José scale shows two distinct pairs of lobes, which, while approximating somewhat at the tip, do not usually come so close together as in A. forbesi. The median lobes are rather long and narrow in appearance, are deeply notched on the outer margin and often on the inner margin nearer the tip than is the outer notch. The second lobes are distinct, well marked, about half the size of the first, rounded at the tips and notched on the outer margin. The spines are as in allied species, one on each lobe, one beyond the second incision and the fourth about halfway from the lobes to the penultimate segment. The plates are quite numerous and easily distinguishable, giving a somewhat fringed appearance that helps to differentiate this species from A. forbesi. There are usually two inconspicuous plates between the median lobes, and two or three long and slender ones at the first incision, three or two often somewhat serrate ones at the second incision and three broad, often two-pointed ones, between the third and

fourth spines. My figure shows that considerable variation occurs even in a single specimen. There are two pairs of incisions, the first between the first and second lobes and the second outside the latter lobe. The first incisions are usually very deep, while both pairs are narrow.

The ends of the lobes are heavily chitinized. The chitinous processes extending along the mesal margins of the median lobes I have not found large and definite so frequently as in A. forbesi. Those on the inner margin of the first incision are of the general type of the latter species and are strongly curved toward the lobe, but are more usually broader at the base of the process, that is, toward the tip and outer edge of the lobe. This is not, however, a very positive difference. The opposite processes nearly equal these in size, which is not the case in A. forbesi. Sometimes I have not distinguished the process of the outer edge of the second incision, but it is often present of about the same size as that of the inner edge.

Ventral glands are wanting even in the adult. The chitinous thickenings of this region are present however as definite and narrow dark areas in well cleared specimens. They are twice bent and of the shape shown in the figure. These will serve to differentiate the adult A. perniciosus from the immature forms of any of these species, even though eggs and young are not present to certify to the maturity of the form.

The anus is of medium size, and is about as far from the ends of the chitinous processes as these are from the tips of the lobes.

The transverse chitinous processes are frequently broad and somewhat irregular. They are not so usually prominent and definite as in A. ostreaeformis. The dorsal pores are comparatively few, small and inconspicuous. They are usually present in traces of three short lines; the first runs from the second incision; the second just laterad of this and the third, consisting of only a few scattering pores, is still farther laterad. Quite frequently a single pore is to be seen anterior to the lateral transverse thickening.

The second stage (pl. 12, fig. 2) is much the same in general arrangement and in the outline of parts except that the ventral chitinous thickenings are parenthesis-shaped and lack definiteness, the dorsal pores are fewer and more scattering, and the plates are not always so easily detected. It may be most easily confounded in this stage with A. forbesi, but it usually displays plates enough in carefully prepared specimens to separate it from that form, and will show also, on greater familiarity, the same difference in relative size of the chitinous processes and in relative position of the lobes which is to be marked in the adult forms.

## Aspidiotus ancylus *Putnam*

PLATE 11, FIGURE 2 AND PLATE 15, FIGURE 1

This species possesses in general but a single pair of lobes, the median ones, which vary considerably in length and outline, but in a fresh adult female they are usually quite long and nearly straight on the inner and outer margins, with the tips rounded and notched on the outer edge, and often also on the inner edge near the tip. Reference to the figures will explain this statement. When worn by long and rough use, the lobes may be much shorter and worn to an oblique curve instead of the form above described. They sometimes approximate slightly at the tips. Occasionally rudiments of other lobes can be made out.

Spines are as usual. Plates are quite numerous fringing the segment; two or three occur at each incision. Comstock speaks of them as usually simple, but they are at least frequently toothed in the mounts I have examined. There are three to four or five irregular and usually simple and slender plates between the third and fourth pairs of spines. The incisions are wide and not deep.

The chitinous processes at the incisions are variable, being often quite large. The one on the inner margin of the first incision is frequently much larger than the opposite one, but they may be subequal. They are of the straighter type, resembling A. ostreaeformis in this rather than A. perniciosus and A. forbesi. The median ones are usually quite large and prominent, but straight.

The ventral glands are in four or five groups: the anterior ones are 0–6, the anterior laterals 6–14, the posterior laterals, 5–8. These numbers are on Comstock's authority. The glands show usually a somewhat linear or scattering arrangement not the compact circular appearance of typical A. ostreaeformis. The ventral thickenings are usually vague and irregular. The anus does not differ strikingly from A. ostreaeformis.

The dorsal pores present quite a range of variation. Dr Marlatt informs me that they are typically much fewer than in A ostreaeformis or A. juglans-regiae. The office collection shows many specimens, however, where they are abundant, appearing usually in three or even four well defined rows. On each side of the median line one row extends from the second incision toward the lateral transverse thickening, another laterad of this extends clear to the outer margin of the same thickening and there is still another, though shorter one, outside of this, while a group of three or a line of four or five appears at the first incision.

Where the pores are fewer the two lines first mentioned can usually be distinguished, but are less crowded than in the extreme form, while the third row is represented by two or three scattering pores or not at all, and the pores at the first incision are two or three in a group close to the ends of the chitinous processes.

The second stage of A. ancylus seems not always definitively different from the same stage of A. ostreaeformis. I have seen in mounts from undoubted A. ancylus material one or two second stage specimens, which had the small, narrow yet distinct second lobes together with absence of the plates that characterize A. ostreaeformis. Similarly, I have seen in A. ostreaeformis mounts second stage specimens that suggest A. ancylus. Of course, it is always possible that the two species are breeding side by side and may be taken at the same time in the younger forms, even if they have not been so taken in the adult stage. It seems to me that, in distinction between the two species, if fringing plates are present, whether or not rudimentary lobes appear, it is pretty surely *not* A. ostreaeformis but is presumably A. ancylus. If plates are not discernible, and a second pair of lobes appears, it is pretty safely the former species. But, where there are neither plates nor second lobes to be discovered, additional evidence should be sought. In any case an identification from second stage material may safely be modified with "probably."

## Aspidiotus ostreaeformis *Curtis*

PLATE 14 AND PLATE 15, FIGURE 2

A. ostreaeformis is one of the large species, the adult female often attaining a diameter of 1½ mm according to Dr Marlatt. He gives an extended description and a beautiful figure on page 81 of the *Proceedings of the 11th annual meeting of the association of economic entomologists* (U. S. dep't agric. div. ent. Bul. 20, n. s.).

The median lobes of this species vary somewhat in shape, but are in general broad with a distinct though shallow notch on the outer margin. The second pair are much smaller but usually easy to distinguish and quite characteristic in shape. They are at least often considerably narrower in proportion than in the specimen represented in my figure. Both pairs are usually heavily chitinized, and sometimes a rudimentary third pair seems to be indicated by the arrangement of chitin beyond the second incision.

The spines are as in allied species; the plates are inconspicuous, but two short stout ones are usually to be discerned at each incision.

The chitinous processes are subequal on the two sides of each incision. They are quite large beside the first incision but are somewhat irregular in shape and usually not so strongly curved on the inner side as is the case in A. perniciosus, and those on the inner edges of the median lobes are variable, sometimes easily detected and in other cases vague and indefinite.

The ventral glands in the adult female are quite numerous and are usually in compact, nearly circular groups, while those of A. ancylus are more likely to be linearly arranged. Dr Marlatt gives the numbers as averaging six for the anterior group, which is usually much the smaller, and 10 or 12 for each of the lateral groups, but the numbers vary quite considerably.

The thickenings in the region of the ventral glands are indefinite and look somewhat like crumplings or foldings of the body wall.

The anus is small and quite distant from the median lobes. The margins, however, run up to embrace it.

Dr Marlatt says:

The dorsal pores are quite characteristic. There are usually two between the first pair of processes and a row of five or six extending from the second pair of processes and after a considerable interval, continued near the lower group of paragenital glands in one or two additional pores. A lateral row of about 10 or 11 pores extends from near the base of the first pair of spines to the lateral chitinous thickenings. Differing from most of its near allies, it has a group of six or seven pores near the basal angles of this segment.

In the next to the last sentence "first pair of spines" means the first spines beyond those associated with lobes, as I think will be seen on study of this figure. The number of these pores varies somewhat, yet there is a certain characteristic general appearance in this arrangement that becomes familiar and at sight suggests A. ostreaeformis to a student of these forms. I have often found three pores in a group at the first incision, and sometimes there are many more in each of the groups than the numbers given above. I have found two lots on willow in our collection where the number and closeness of arrangement of these pores suggest A. juglans-regiae, so that Dr Marlatt, to whom the specimens were submitted, advances interbreeding as a possible explanation of the phenomena. The lobes are three on each side of the median line in this willow form, and the ventral glands are more numerous than in typical A. ostreaeformis, while the specimens are larger in size.

In the second stage the two pairs of lobes are usually distinctly present, though the second are minute. Sometimes a hint of the rudimentary third ones can be discerned. The incisions are wide and not

deep. The plates and spines are as in the adult; the chitinous processes are subequal and similar to those in the adult though of course smaller; the ventral glands wanting, ventral thickenings parenthesis-shaped; anus and transverse thickenings as in the adult. The dorsal pores are fewer than in the adult but are plainly of the same general arrangement, with two or three at the first incision, a row from the second incision consisting usually of three pores and the lateral row with about six running up to the lateral transverse thickening. There are usually one or two pores still laterad of this and generally two or more to represent the basal angle group. This is closely similar to the second stage of A. ancylus, but may be distinguished in carefully prepared specimens by the absence of the fringing plates which characterize the latter. Usually the difference in the general shape of the lobes and the deeper, narrower incisions of A. perniciosus and A. forbesi will distinguish the second stages of these two species from those of A. ostreaeformis to one at all familiar with these forms.

## SCALE INSECTS, COCCIDAE, IN NEW YORK STATE

This list of 78 species gives some idea of the number of scale insects farmers, horticulturists, nurserymen and those interested in greenhouses have to contend with. It also has value in that it indicates about what forms may be found on certain plants in the state, though the list of food plants of a number of species could undoubtedly be considerably increased by farther collecting. Those occurring on any one plant can easily be ascertained by referring to the index, where the species are listed under the names of the plants on which they may be found. Many of these scale insects are not injurious, but there are also a number of pests of considerable importance. This list is largely based on previous records, and many additions would undoubtedly result from special collecting. An effort has been made to exclude unreliable records. Some of the earlier determinations on which records depend may be erroneous, but it is almost impossible to eliminate this source of error.

It is a pleasure to acknowledge the assistance of several coworkers in the preparation of this list. Messrs Comstock, Howard, King, Lowe, Parrott, Pettit and Slingerland have very kindly called my attention to overlooked records, given suggestions as to the synonymy, and also placed at my disposal their own unpublished notes.

## Coccinae

Eriococcus azaleae Comst., on azalea in a greenhouse, Geneva. Comstock, 2d Cornell rep't. p. 132; on wild azalea (Azalea nudiflora), Coy glen, Ithaca. Insect life. 3:52.

Gossyparia ulmi Geoff., elm bark louse, on English, Scotch, Camperdown, American and slippery elm. It is known to occur at the following places: Albany, Catskill, Delmar, Flushing, Ghent, Marlboro, Ogdensburg and Rochester. *See* rep'ts N.Y. state ent. Also Chatham and Loudonville. Howard in letter.

Ripersia maritima Ckll., on roots of Spartina, Hempstead Harbor. Cockerell, Insect life. 7:42.

Dactylopius citri Risso, in greenhouses, New York. Howard in letter.

Dactylopius longispinus Targ. (D. adonidum in error) common "mealy bug." This insect is probably present in most greenhouses in the state.

Dactylopius trifolii Forbes, on red clover, Ithaca. R. H. Pettit in letter.

Dactylopius sp. on quince. Lowe, Geneva Bul. 180. p. 128.

Dactylopius sp. (D. ?cockerelli) on grass roots beneath a flat stone and attended by Lasius flavus, Geneva, May 30, 1901. Parrott in letter.

Phenacoccus aceris Sign. (syn. Pseudococcus aceris Geoff.), on maple leaves, Athens. N. Y. state ent. Rep't. 15:616. At Brooklyn and Middletown on maple. Howard in letter.

## Asterolecaniinae

Asterolecanium variolosum Ratz. (syn. A. quercicola Auctt.) oak scale insect on English oak, Newburgh. N. Y. state ent. Rep't. 10:519. Geneva and Cortland. ——— 15:617. On oak, Cortland and golden oak at New York. Howard in letter. At Rochester. Slingerland in letter.

## Ortheziinae

Orthezia americana Walk., on burdock, Ithaca. Comstock, Agric. rep't. 1880. p. 349.

Orthezia insignis Doug., greenhouse Orthezia, probably a very common greenhouse pest, on coleus, Rye and Ithaca, Lounsbury, Mass. Agric. coll. Rep't. 1895. p. 112–13.

### Lecaniinae

Kermes galliformis Riley, oak Kermes, on oak, Middletown. N. Y. state ent. Rep't. 12 : 317. Several species have passed under this name, but the true K. galliformis probably occurs in this state. Oak at Brooklyn. Howard in letter.

Kermes pettiti Ehrh., on oak, Ithaca. King, Psyche. 9 : 81.

Kermes trinotatus Bogue, on oak, Albany. Can. ent. 32 : 205.

Lecanium antennatum Sign., on oak. Signoret, Essai sur les cochenilles. 1873. p. 413; Comstock, 2d Cornell rep't. p. 132.

Lecanium armeniacum Craw, on grape, Erie county. N. Y. state ent. Rep't. 14 : 260; on English gooseberry, Geneva, Brighton. ——— 15 : 617; on Prunus simoni, Defreestville, state collection.

Lecanium caryae Fitch,[1] on hickory. Fitch rep't. 3 : 125; Comstock, 2d Cornell rep't. p. 133. At Geneva. Lowe, in letter.

Lecanium cerasifex Fitch, on cherry. Fitch rep't. 3 : 50; Comstock, 2d Cornell rep't. p. 133; on maple, oak, Menands, Geneva. N. Y. state ent. Rep't. 14 : 261; on peach, Geneva. ——— 15 : 617; on apple, Union Springs. ——— 16 : 1044; on white ash, Stanley, state collection. On plum, Geneva. Lowe in letter.

Lecanium corylifex Fitch, on hazelnut. Fitch rep't. 3 : 155; Comstock, 2d Cornell rep't. p. 133.

Lecanium cynosbati Fitch, on wild gooseberry. Fitch rep't. 3 : 118; Comstock, 2d Cornell rep't. p. 133.

Lecanium fitchii Sign., on raspberry or blackberry. Signoret, Essai sur les cochenilles. 1873. p. 404; Comstock, 2d Cornell rep't. p 133.

Lecanium fletcheri Ckll. King, Can. ent. 31 : 141. At Ithaca. Pettit in letter.

Lecanium hemisphericum Targ., common in greenhouses. Comstock in letter; at Brighton. Howard in letter.

Lecanium hesperidum Linn., common in greenhouses and on house plants. On sweet bay, fern and lemon, Buffalo, Alden and Nyack. Howard in letter.

Lecanium juglandis Bouché, on butternut. Fitch rep't. 3 : 145 (as L. juglandifex); Comstock, 2d Cornell rep't. (as L. juglandifex Fitch) p. 134; on plum, Rochester, Menands. N. Y. state ent. Rep't. 10 : 518.

Lecanium lintneri Ckll. & Bennett, on sassafras, Lake Mohonk Cockerell, Am. naturalist. 29 : 381.

1 Species described by Dr Fitch or received from him by others are probably New York species and are therefore included in this list.

Lecanium nigrofasciatum Perg., peach Lecanium, on sugar maple, Poughkeepsie, Ithaca. Pergande, U. S. dep't agric. div. ent. Bul. 18, n. s. p. 27. At Brooklyn. Howard in letter. On soft maple, Albany, state collection.

Lecanium persicae Fabr., on peach. Comstock, 2d Cornell rep't. p. 134; at Jamaica. Howard in letter.

[1]Lecanium prunastri Fonsc., New York plum scale insect, on cherry, Ardisia crenulata, Albany, Flushing. N. Y. state ent. Rep't. 14 : 261. A serious enemy of the plum in western New York; many localities have been recorded. *See* Cornell Bul. 83, 108, ——— rep't '95, Geneva Bul. 136.

Lecanium pruinosum Coq., on grapevine, Brighton. N. Y. state ent. Rep't. 15 : 617.

Lecanium quercifex Fitch, on white oak. Fitch rep't. 5 : 25; Comstock, 2d Cornell rep't. p. 135.

Lecanium quercitronis Fitch, on black oak. Fitch rep't. 5 : 25; Comstock, 2d Cornell rep't. p. 135.

Lecanium ribis Fitch, on currant. Fitch rep't. 3 : 109; Comstock, 2d Cornell rep't. p. 135; On Ostrya and Carpinus, Albany. Howard in letter.

Lecanium tulipiferae Cook, tulip tree scale insect, Rochester. N. Y. state ent. Rep't. 10 : 518; on tulip tree, Somers. ———13 : 374; on Magnolia soulangea, Fishkill, at Highland Falls. ——— 14 : 261; ———15 : 617; Mount Vernon. ———16 : 1044; at Watkins and Nyack. Howard in letter. At Poughkeepsie, Slingerland in letter.

Lecanium n. sp. on Pinus rigida, Karner, state collection.

Lecanium n. sp. on maple, Albany. Howard in letter.

Pulvinaria acericola Walsh and Riley, maple leaf Pulvinaria, on maple, Ithaca. Howard. U. S. dep't agric. div. ent. Bul. 22, n. s. p. 17.

Pulvinaria innumerabilis Rathv., cottony maple tree scale insect, on soft maple, sugar maple, elm and grape, numerous localities recorded. *See* rep'ts N. Y. state ent.

Pulvinaria maclurae Kenn. King, Can. ent. 31 : 143. This record is open to question, though this species may occur in the state.

## Diaspinae

Aspidiotus abietis Schr., on pitch pine, Ithaca. Comstock, Agric. rep't. 1880. p. 306; (syn. A. pini) on under surface of hemlock

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1 Mr King has found in material sent from New York state as this species L. juglanis Bouché and L. rotundum Sign.

leaves, Ithaca. Comstock, 2d Cornell rep't. p. 57; on pitch pine, Karner, state collection.

Aspidiotus aurantii Mask., in greenhouses, New York Howard in letter.

Aspidiotus ancylus, Putn., Putnam's scale insect. It occurs on many food plants and has been recorded from numerous localities. *See* p. 327.

Aspidiotus betulae Baer, on horse-chestnut, Buffalo, state collection.

Aspidiotus comstocki Johns., on sugar maple, Ithaca. Ill. state lab. nat. hist. Bul. 1896. 4:385.

Aspidiotus forbesi Johns., cherry scale insect, on apple, Manchester. N. Y. state ent. Rep't. 16:1044; on plum, Geneva. Howard in letter; on pear, Geneva, state collection. *See also* p. 331.

Aspidiotus juglans-regiae Comst., English walnut scale insect, on locust, pear and cherry, New York state. Comstock, 2d Cornell rep't. p. 61. Probably on maple, Albany, state collection. On willow, Fredonia. Slingerland in letter. At Brighton. Howard in letter.

Aspidiotus hederae Vall. (syn. A. nerii Bouché), white scale insect of ivy, common in greenhouses. *See* p. 334.

Aspidiotus lataniae Sign. (syn. A. cydoniae Comst.), on palm in greenhouse, Cobleskill. On Areca lutescens, Kentia fosteriana, Albany, state collection.

Aspidiotus ostreaeformis Curtis, European fruit scale insect, occurs in many localities. *See* notice on p. 325.

Aspidiotus perniciosus Comst., pernicious, or San José scale, occurs on many food plants and has a wide distribution. *See* notice on p. 309–11.

Aspidiotus punicae Ckll., Seward. Howard in letter.

Aspidiotus ulmi Johns., on catalpa, Buffalo, on elm, Le Roy, Albany, state collection.

Aspidiotus uvae Comst., possibly in the state, as a specimen without locality label occurs in the state collection.

Pseudaonidia species on Camellia japonica at New York. N. Y. state ent. Rep't. 15:616.

Chrysomphalus aonidum Linn. (syn. C. ficus Ashm.), on palm in greenhouse at Gloversville. Insect life. 7:360; on Ficus ?carica, Strelitzia reginae, Kentia belmoreana, Coe-

logyne cristata, Monstera deliciosa, Phoenix reclivata, P. dactylineata, ivy, Chinese dwarf orange, Albany, state collection.

Chrysomphalus dictyospermi Morg., on ivy, Coelogyne cristata, Kentia belmoreana, K. fosteriana, Areca lutescens, in Albany greenhouses, state collection.

Diaspis calyptroides Costa (syn. D. cacti Comst.), cactus scale insect, on cactus, Ithaca. Comstock, 2d Cornell rep't. p. 91; on Cereus grandiflora, New York, on Epiphyllum truncatum, Albany, state collection.

Diaspis carueli Targ., juniper scale insect, on Irish juniper, Sing Sing. N. Y. state ent. Rep't. 14 : 262.

Diaspis ostreaeformis Sign., imported from France on nursery stock in 1898, but it was probably exterminated; letter from M. V. Slingerland. There is danger of importing this insect in the future, even if it is not established here at present.

Aulacaspis bromeliae Kern. on Corypha australis, Albany greenhouse, state collection.

Aulacaspis boisduvalii Sign., a greenhouse or house species on orchid, Gouverneur. N. Y. state ent. Rep't. 14 : 262. On Seaforthia elegans, Phoenix reclivata, P. dactylineata, P. canariensis, Strelitzia reginae, Livistonia rotundifolia, orchid, variegated pineapple, palms, Albany, state collection.

Aulacaspis rosae Sandb., rose scale, on rose, Brooklyn. N. Y. state ent. Rep't. 7 : 384; on blackberry, Brighton.———16 : 1045; on blackberry, Geneva, Lebanon Springs; on raspberry, Onteora Mts, Greene co., and at Geneva. Howard in letter; At Ithaca, Slingerland in letter. On blackberry, Stanley, on raspberry, Hudson, state collection.

Howardia elegans Leon., in a greenhouse on Cycas revoluta, Altamont. N. Y. state ent. Rep't. 16 : 1045; on Zamia integrifolia and Cycas revoluta, Albany, state collection.

Parlatoria pergandii Comst., orange chaff scale insect, on orange, Sing Sing. N. Y. state ent. Rep't. 14 : 262; on tangerine, New York.———15 : 618. A greenhouse species. Geneva on orange. Howard in letter.

Parlatoria proteus Curtis on Vanda suava in greenhouse at Ithaca. R. H. Pettit in letter.

Parlatoria theae Ckll. (syn. P. viridis Ckll.) on imported Japanese maples. N. Y. state ent. Rep't. 15 : 618. The lot was seized and fumigated. This species was subsequently imported on another lot, which was also treated. It is very probable that this insect has been imported before, and it may prove hardy in our climate.

Mytilaspis citricola Pack., orange scale insect. Occurs on oranges in the markets and probably on orange trees in greenhouses. On lemon at Geneva. Howard in letter.

Mytilaspis gloverii Pack., a greenhouse species. King, Can. ent. 31 : 229.

Mytilaspis pomorum Bouché, the appletree bark louse, a common, widespread species with a large number of food plants. *See* p. 297, 298.

Pinnaspis pandani Comst., palm scale, in greenhouses, New York, state collection.

Chionaspis americana Johns., elm Chionaspis, on elm, Brooklyn. Cooley. Mass. expt. sta. Special bul. 1899. p. 43. At Cohoes, Geneva. Howard in letter. On American elm, Albany, state collection.

Chionaspis euonymi Comst., Euonymus scale insect, on Euonymus, lilac, Prunus pissardi at Fishkill, Greatneck and Irvington. N. Y. state ent. Rep't. 15 : 618; on Celastrus scandens, Blauvelt, state collection. At Brooklyn. Howard in letter. At Tarrytown, Slingerland in letter.

Chionaspis furfura Fitch, scurfy bark louse, a very common species. *See* p. 302–3 for food plants and distribution.

Chionaspis lintneri Comst., Comstock on alder, Viburnum lantanoides. 2d Cornell rep't. p. 103; on Cornus, Rochester, state collection.

Chionaspis pinifoliae Fitch, pine leaf scale insect, on pines, Matteawan. N. Y. state ent. Rep't. 7 : 384; at Albany, Geneva. ——— 15 : 618; at Saratoga, state collection. At Newburgh, Fayetteville. Howard in letter. At West Somerset. Slingerland in letter A common species with a wide distribution.

Chionaspis salicis-nigrae Walsh, on willow, Ithaca. Comstock, Agric. rep't. 1880 (C. salicis in error) p. 320. On Cornus alternifolia, Kashong glen near Geneva. Parrott in letter.

Hemichionaspis aspidistrae Sign., on fern in greenhouse, Ithaca. R. H. Pettit in letter, on Asplenium viviparum, and sago palm or Cycas revoluta, Albany, state collection.

# EXPLANATION OF PLATES

Plates 1-7 were executed from nature, under the author's direction, by L. H. Joutel of New York.

## PLATE 1

### Appletree bark louse

*Mytilaspis pomorum* Bouché

FIG.

1 Eggs and two empty, shriveled shells, very much enlarged
2 Active young, very much enlarged
3 Young just after they have settled on the bark, very much enlarged
4 Partly grown scales with an old one, much enlarged
5 Partly grown young still more enlarged
6 Male scale, much enlarged
7 Female scale, much enlarged
8 Female scale reversed, showing shriveled parent and eggs, much enlarged
9 Female scales on poplar bark, natural size
10 Female, very much enlarged

## PLATE 2

### Scurfy bark louse

*Chionaspis furfura* Fitch

FIG.

1 Female scale broken open to reveal the purplish eggs within, very much enlarged
2 Active young, very much enlarged
3 Partly grown scales, much enlarged
4 Adult female and two male scales, much enlarged
5 Female scale reversed, showing egg and shrunken body of mother, very much enlarged
6 Male scale, very much enlarged
7 Scales on twig, natural size
8 Male scales on bark, much enlarged
9 Adult female just before oviposition, much enlarged

## PLATE 3

## Pernicious or San José scale insect

*Aspidiotus perniciosus* Comstock

FIG.

1 Recently established scale in white stage on green twig, very much enlarged. (Note red coloring around it)

2 Recently established young on green twig natural size. (Note red coloring around scales)

3 Pear showing young scales and the red discoloration, natural size. (Same is shown on the leaf)

4 Young scales in white stage on twig, natural size

5 Mass of old scales, some young black ones and some in white stage on a twig, natural size

6 Group of yellowish adult scales, enlarged

7 Group of dark adult scales surrounded by many young black ones, enlarged

8 Adult male scale, very much enlarged

9 Adult female scale, very much enlarged

10 Adult female, very much enlarged

11 Active young, very much enlarged

12 Perfect male, very much enlarged

13 Young in black stage, very much enlarged

## PLATE 4

## European fruit scale insect

*Aspidiotus ostreaeformis* Curtis

FIG.

1 Recently established young, greatly enlarged

2 Young in white stage, natural size

3 Portion of above, much enlarged

4 Half grown scales, much enlarged

5 Half grown scales, somewhat enlarged

6 Piece of badly infested bark, natural size

7 Portion of twig showing mass of scales, much enlarged

8 Male scale, very much enlarged

9 Female scale, very much enlarged

10 Female as removed from under a scale, very much enlarged

11 Active young, very much enlarged

PLATE 5

## Putnam's scale insect

*Aspidiotus ancylus* Putnam

FIG.
1 Group of young scales on pear, enlarged
2 Several young scales, greatly enlarged
3 Portion of currant twig with young scales, natural size
4 Same much enlarged
5 Half-grown scales on white birch, enlarged
6 Badly infested twig of Ilex verticillata, enlarged
7 Portion of above, greatly enlarged
8 Male scale, very much enlarged
9 Female scale, very much enlarged
10 Female as removed from under a scale, very greatly enlarged
11 Young scale insect, very greatly enlarged

PLATE 6

## Cherry scale insect

*Aspidiotus forbesi* Johnson

FIG.
1 Dorsal view of white scale, very much enlarged
2 Same from a nearly side view, very much enlarged
3 Group of young scales, much enlarged
4 One scale from the above, still more enlarged
5 Two half-grown scales, very much enlarged
6 Twig infested with full-grown scales, natural size
7 A group of scales from the above, more enlarged
8 Female scale, very much enlarged
9 Two male scales, very much enlarged
10 Female as removed from under a scale, very much enlarged

PLATE 7

## White scale insect of the ivy

*Aspidiotus hederae* Vallot

FIG.
1 Female as removed from under her scale, very much enlarged
2 Active young, very much enlarged
3 Young scale, very much enlarged
4 Adult female scale, very much enlarged
5 Shriveled female as found under the scale after all her eggs are laid, very much enlarged

FIG.
6 Group of female and half-grown scales, much enlarged
7 Spray of ivy showing scales on upper and under surface of the leaves and on the stem, natural size
8 Yellowish eggs and young found under a scale, very much enlarged

PLATE 8

## Effects of undiluted crude petroleum

Tree 93, lombard plum, was sprayed with crude petroleum April 11, and the tree photographed July 2.

Tree 8, one of the same variety, was similarly sprayed with a 20% mechanical emulsion of crude petroleum, and the tree photographed July 2. Compare the two in order to gain an idea of the effect of crude petroleum.

PLATE 9

## Effects of undiluted crude petroleum

Tree 101, a seckel pear, was sprayed with undiluted crude petroleum, April 11, and photographed July 2.

The king appletree was painted with crude petroleum Dec. 1, 1899, and photographed May 21. This tree died during the summer, throwing out scarcely a leaf.

Tree 110, a Kieffer pear sprayed with Good's whale oil soap April 11, is represented by way of contrast.

PLATE 10

Fumigating tent in operation. The tent is lifted bodily from the tree with the aid of the tackle and pole. The hood was kept distended in this instance in order to make the cubic contents more constant.

PLATE 11

FIG.
1 Diagrammatic representation of anal plate of adult female scale insect, showing peculiar organs. Those belonging specially to the ventral surface are represented on the left half of the figure; those of the dorsal surface on the right.

*a*, *a* lobes, heavily chitinized at tip

*b*, *b*, *b*, *b* spines, on ventral and on dorsal surfaces, the latter slightly out of focus

*c*, *c*, *c*, *c* plates, of varying forms

*d*, *d*, *d*, *d* incisions in margin of anal segment

FIG.

*e, e, e, e, e, e, e, e* chitinous processes, or thickened margins of incisions
*f* general thickening inward of body wall
*g, g, g* ventral grouped glands, or spinnerets
*h* ventral chitinous thickening
*i* vagina
*k, k* transverse chitinous thickenings of dorsal wall
*l, l, l, l* dorsal pores, showing different appearances seen in focusing
*m, m* wax ducts, within body
*n* anus

2 Aspidiotus ancylus Putnam, adult female. Note fringing plates, the single pair of lobes, and the linear arrangement of ventral glands. Compare with A. ostreaeformis, plate 14.

PLATE 12

FIG.

1 Aspidiotus forbesi Johnson, adult female. Note chitinous thickenings and form of lobes. Compare with figure 2.

2 Aspidiotus perniciosus Comstock, adult female. Ventral glands are absent. Note plates.

PLATE 13

FIG.

1 Aspidiotus forbesi Johnson, second stage. Compare with adult, plate 12, figure 1, and with A. perniciosus, second stage, on plate with it.

2 Aspidiotus perniciosus Comstock, second stage. Compare with adult, plate 12, figure 2.

PLATE 14

Aspidiotus ostreaeformis Curtis, adult female. Note form of second lobes and grouping of ventral glands. Compare with A. ancylus, plate 11, figure 2, and with the other species figured.

PLATE 15

FIG.

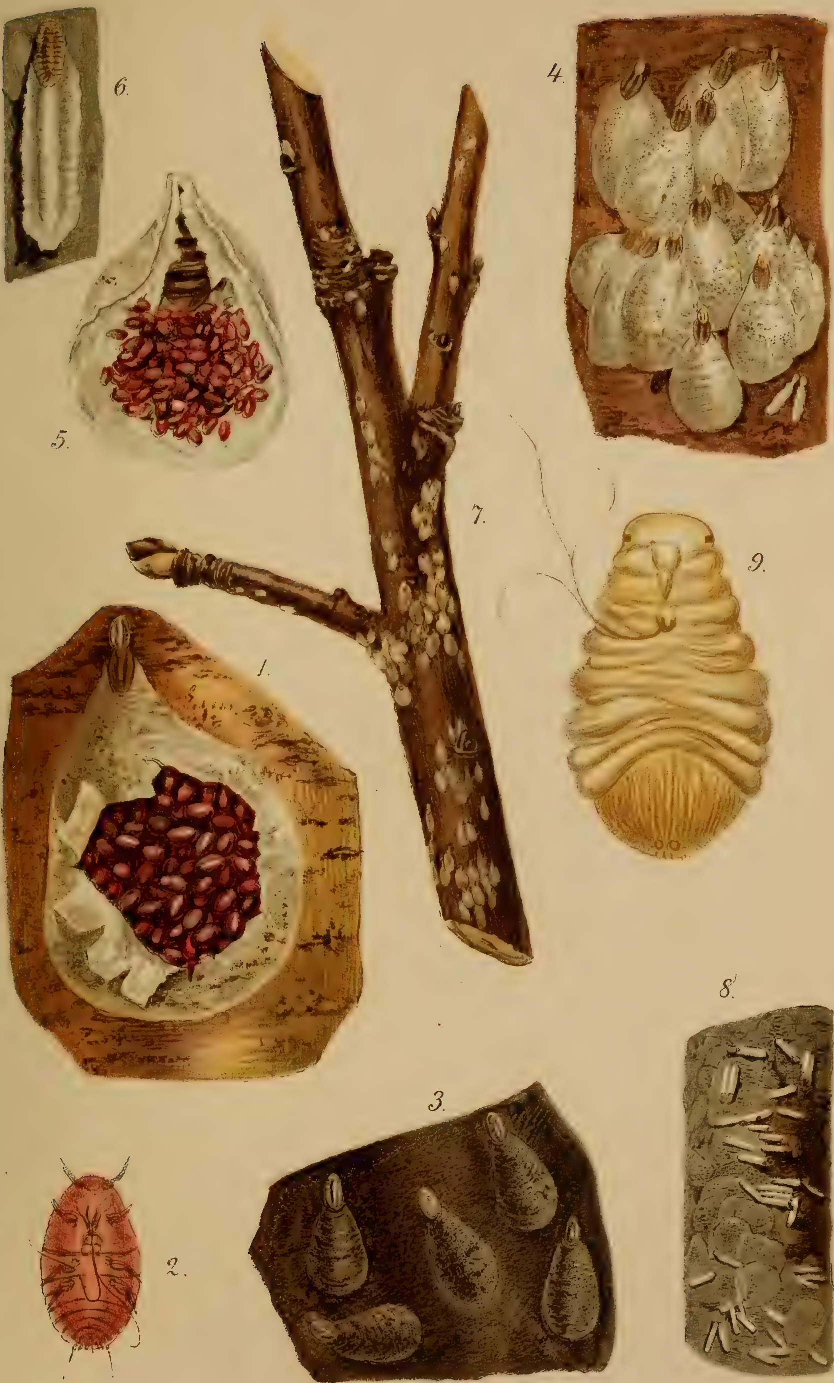
1. Aspidiotus ancylus Putnam, second stage. Note plates in comparison with A. ostreaeformis at figure 2. Compare also with adult, plate 11, figure 2.

2 Aspidiotus ostreaeformis Curtis, second stage. Compare with adult, plate 14.


L. H. Joutel, 1900

James B. Lyon, State Printer

Appletree bark louse




L. H. Joutel, 1900

James B. Lyon, State Printer

Scurfy bark louse


L. H. Joutel, 1900

James B. Lyon, State Printer

Pernicious or San José scale insect

Plate 4


L. H. Joutel, 1900

James B. Lyon, State Printer

European fruit scale insect


L. H. Joutel, 1900

James B. Lyon, State Printer

Putnam's scale insect


L. H. Joutel, 1900

James B. Lyon, State Printer

Cherry scale insect


L. H. Joutel, 1900

James B. Lyon, State Printer

White scale insect of the ivy

Tree 8 Lombard plum Photo July 2
20% KEROSENE

Tree 93 Lombard plum Photo July 2
CRUDE PETROLEUM

(Compare the two trees)

Tree 101 Seckel pear Photo July 2
CRUDE PETROLEUM

Tree 110 Kieffer pear Photo May 14
WHALE OIL SOAP

Painted Dec. 1 King apple Photo May 21
CRUDE PETROLEUM

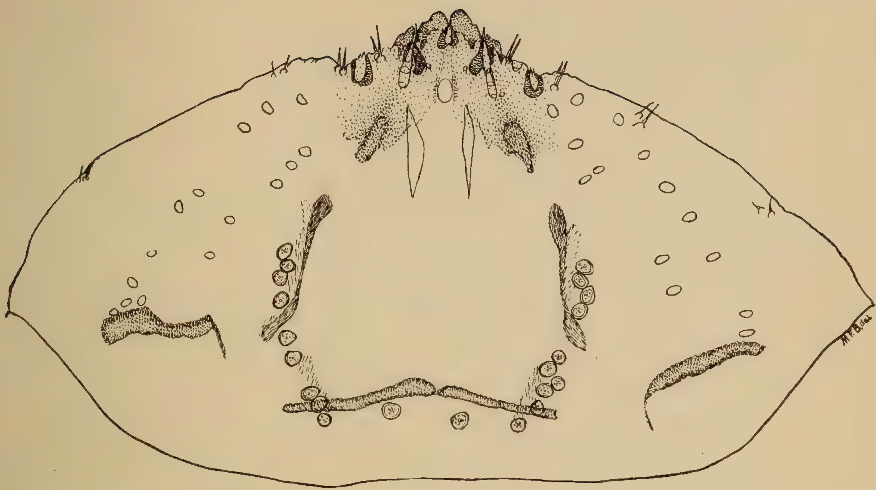
Photo April 21

Fumigating tent in operation

1

2

1 Diagrammatic figure of anal plate of scale insect showing peculiar organs
2 Aspidiotus ancylus, adult female



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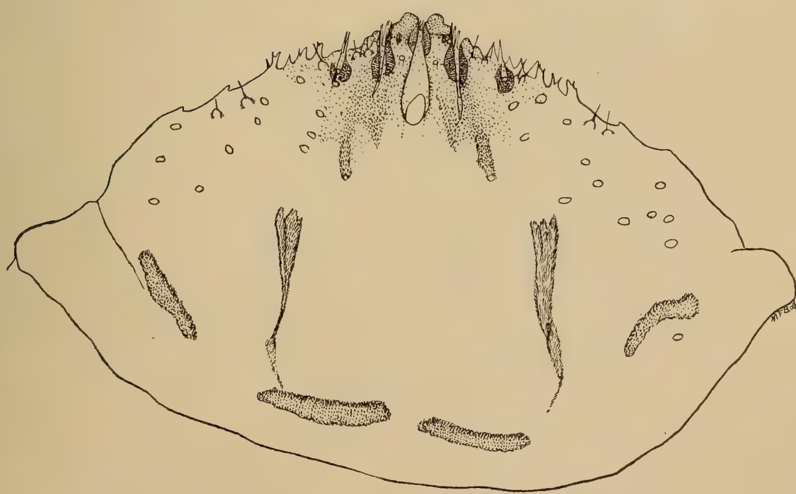
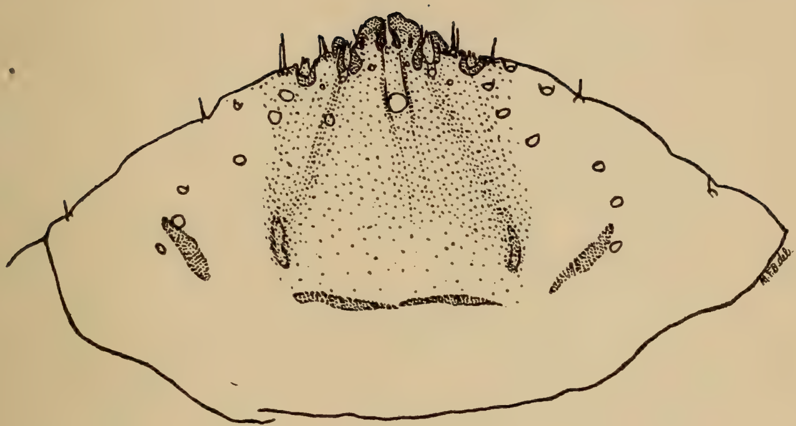


2

1 Aspidiotus forbesi, adult female
2 Aspidiotus perniciosus, adult female



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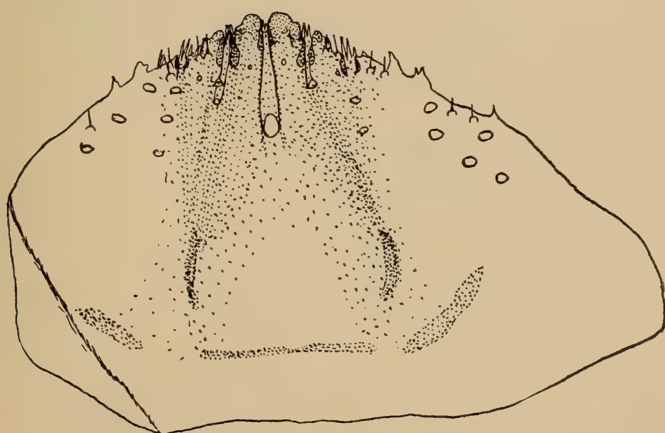
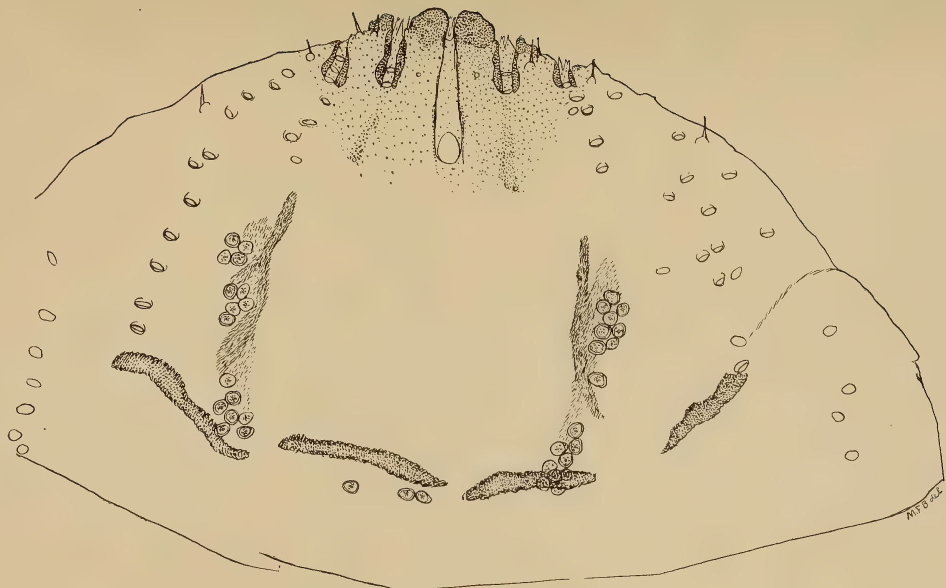


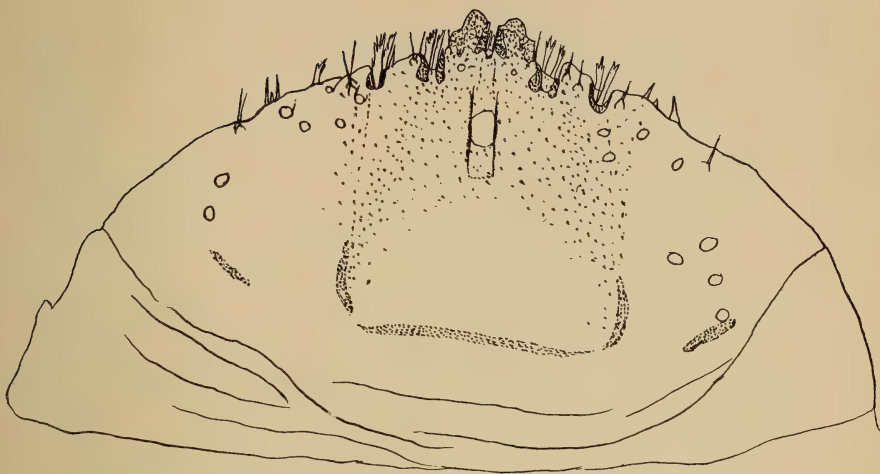
2

1 Aspidiotus forbesi, second stage
2 Aspidiotus perniciosus, second stage

Plate 14




Aspidiotus ostreaeformis



1

2

1 Aspidiotus ancylus, second stage
2 Aspidiotus ostreaeformis, second stage

# INDEX

The superior figure points to the exact place on the page in ninths; e. g. $357^9$ means page 357 beginning in the ninth ninth of the page, i. e. almost at the bottom.

(*Pages 379–80 were bulletin cover pages*)

University of the State of New York

# New York State Museum

FREDERICK J. H. MERRILL *Director*

Bulletin 47 September 1901

# AQUATIC INSECTS IN THE ADIRONDACKS

A study conducted at the Entomologic field station, Saranac Inn N. Y. under the direction of

Ephraim Porter Felt D. Sc. *State entomologist*

BY

JAMES G. NEEDHAM Ph.D.

*Professor of biology, Lake Forest university*

AND

CORNELIUS BETTEN M.A. *Assistant*

University of the State of New York

# New York State Museum

Bulletin 47 September 1901

# AQUATIC INSECTS IN THE ADIRONDACKS

## PREFACE

The following account presents in part the results obtained by a close study of aquatic insects in one locality. Saranac Inn proved an exceptionally favorable place for investigations of this character, and the labor of two earnest, enthusiastic workers made the entomologic field station a very successful institution. Only 10 weeks in the field sufficed for working out in more or less detail the life histories of about 100 species, the discovery of 10 new species and two new genera, and for material additions to the list of insects known to occur in the state. The bred Chironomidae, the material representing the suborder Zygoptera of the dragon flies and the collection of fish stomachs, which have not been included in this report, should give, when worked up next year, a large number of additional interesting and valuable facts.

This work, even when all available data are brought together, does not complete the desirable investigations along this line. Dr Needham's report, though thorough so far as it goes, is largely of a preliminary nature and will prove an excellent basis for subsequent work. It is physically impossible to do more than this with 10 weeks in the field. The solving of the complex interrelations existing between the various aquatic forms requires persistent efforts extending through a number of seasons, and the results thus obtained should be verified by studies in other localities. This is a large field requiring the serious attention of the botanist and zoologist, using these terms in the general sense, and the practical value of these studies can not be fully available till such an investigation is made along broad and comprehensive lines. A study of this character could be conducted at a comparatively small outlay, and would prove of great benefit to fish culture, and should result in the rearing of many more fish in the fresh waters of New York state.

E. P. Felt

*State entomologist*

*Part* 1

## INTRODUCTORY

### THE UNDERTAKING, LOCATION, OBJECTS, METHODS AND RESULTS

"To collect and study the habits of aquatic insects, paying special attention to the conditions necessary for the existence of the various species, their relative value as food for fishes, the relations of the forms to each other, and their life histories": such were the instructions under which I went to Saranac Inn, to take charge of the opening session of the entomologic field station. Arrangements had been previously made with state entomologist Dr E. P. Felt, that the session should extend from June 15 to August 20. I arrived at Saranac Inn on the evening of June 12, and at once began looking the ground over. Dr Felt came on the 14th, and spent the day with me canvassing the situations to be studied. My assistant, Cornelius Betten, arrived on the 15th, and the regular work of the session was at once begun, to be continued without cessation to the date of closing.

Through the courtesy of the New York state fisheries, game and forest commission the station was furnished with working quarters in the hatchery building, and was allowed the use of parts of the hatchery equipment, not then otherwise needed. There were three very considerable advantages to our work in this arrangement: 1) the use of several hatching troughs with their continuous supply of well aerated water for insect breedings, 2) the use of a carpenter's bench and tools for the construction of special breeding cages, 3) the use of a boat for collecting.

We were soon supplied with a special equipment for the collecting and rearing of aquatic insects, that was excellently adapted to our needs, and without which the work hereinafter recorded could not have been done. Our sincere thanks are due Dr Felt for his care in providing exactly the apparatus asked for. Save for the first 10 days, during which we were unable to find living quarters within 2 miles of our field of operations, we had the still farther great advantage of close proximity to good collecting grounds.

The season was one of excessive rainfall. The first week of the session and the last one were comparatively dry; but, for the remainder, it was raining more than a third of the time. Thus collecting was greatly interfered with, sweeping of vegetation was almost prevented, trap lanterns were flooded night after night and their catch spoiled, and regularity in field operations was made impracticable.

The routine work of the station consisted in collecting and studying aquatic insects in all their stages of development, in conducting feeding

experiments, in making quantitative studies of the life of certain situations, in gathering the materials for the study of the natural and habitual food of trout, bullfrogs, and some of the larger species of dragon flies, in running trap lanterns and sending their nightly catch to the state museum, etc.

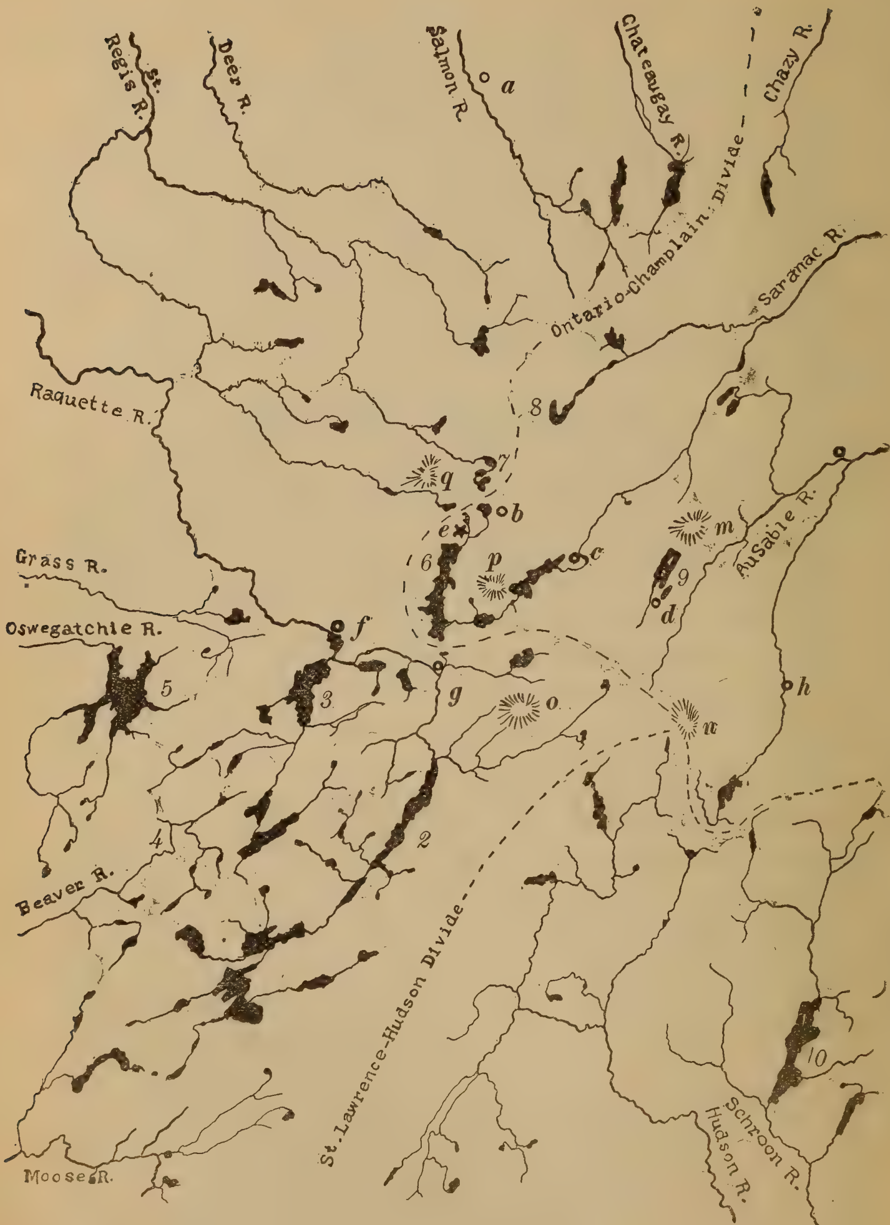
Besides three official visits made by Dr Felt during the course of our session, our station was visited for a week or more at a time by three scientific friends, who, while there, participated in our operations, and, while collecting for themselves, gathered also valuable materials and information for us. These were Louis W. Swett of Malden Mass., H. N. Howland of Austin Ill., and Dr O. S. Westcott of Chicago. It is a pleasure to acknowledge the assistance gratuitously rendered by these gentlemen.

## Biologic features of the locality

As is well known, the Adirondack region of northeastern New York is an extensive area of forest, having an average elevation of about 1800 feet. Its eastern half is covered with a succession of low mountain ranges, whose general n n e-s s w trend is indicated on the accompanying map (map 1) by the trend of the streams which occupy the narrow valleys between them. The western half is a region of lakes and swamps and bogs, with scattered mountains and hills and ridges.

Map 1 shows the principal streams that participate in the drainage of the Adirondack region, the principal lakes, and some of the mountains. It will be observed that the lake region of the Adirondacks is drained principally through Racket river into the St Lawrence.

Saranac river is the only one on the Champlain side that drains any considerable part of the lake country. Our station at Saranac Inn was at the head of the Saranac drainage system. Map 2 shows the immediate field of our operations. As stated above, the hatchery was our working headquarters. We did more collecting from Little Clear creek right on the hatchery grounds than from any other equal water area, and obtained more material of value there than in all other places combined. More or less regular collecting was done, however, from the three propagating ponds, Little Clear, Little Green and Bone, and from Little Bog pond, southwest of the railroad station. Two collecting trips were made to each of the following places: Colby pond, at the western outskirts of the village of Saranac Lake; Stony brook, just north of Axton; and St Regis pond, at the end of the carry from Little Clear. The mornings and evenings of the first week of the session were spent gathering material about the south shore of Lake Clear, or Big Clear at Otisville.




Map 1 Drainage map of the Saranac region

*Lakes:* 1 Raquette; 2 Long; 3 Tupper; 4 Ne-ha-sa-ne; 5 Cranberry; 6 Upper Saranac; 7 St Regis; 8 Rainbow; 9 Placid; 10 Schroon
*Towns:* *a* Malone; *b* Saranac Junction; *c* Saranac Lake; *d* Lake Placid: *e* Saranac Inn; *f* Tupper Lake *g* Axton; *h* Keene Valley
*Mountains:* *m* Whiteface; *n* Marcy (Tahawus); *o* Seward; *p* Boot Bay; *q* St Regis

Saranac Inn is very near the Champlain-Ontario divide, on a sandy, undulating mountain upland in the midst of almost unbroken forest. Round about it are numerous lakes, ponds, bogs and clear, slow flowing streams, with here and there a low ridge built on outcropping gneiss, or a sharply rising, densely wooded hill. There is more of sand and less of rock, more of water area and less of mountain, than in most places in the Adirondacks; and the descent of the streams is much more gentle.

The forests are composed, as elsewhere, mainly of hemlock and balsam, beech, yellow birch and maple, pine and spruce having been mainly removed by lumbering, and oaks and our common nut-bearing trees never having been present in the Adirondack woods. In the drier and denser parts of the woods, where there is little undergrowth, the hobblebush, Viburnum alnifolium Marsh., spreads its broad leaves on straggling branches to catch the scanty sunlight, while Indian pipe, Monotropa uniflora Linn., star flower, Trientalis americana Pursh, rattlesnake plantain, Peramium pubescens (Willd.) MacM., Indian cucumber root, Medeola virginiana Linn., the yellow Clintonia, Clintonia borealis Linn., the dwarf Smilacina, Vagnara trifolia (L.) Morong, several pretty species of ground pine, Lycopodium, and innumerable mushrooms spring from the loose leaf mold. Recently burned tracts are mainly in the possession of the bracken fern, Pteris aquilina Linn., the fireweed, Chamaenerion angustifolium (Linn.) Scop., poplars and wild cherry. In wet places in the woods occur stemless lady's slippers, Cypripedium acaule Ait., in the shadows, and in the openings grow cinnamon fern, Osmunda cinnamomea Linn., and clumps of the red elder berry, Sambucus pubens Mx., which in midsummer, when the fruit is scarlet, are strikingly beautiful. In the bogs the trees are balsam and tamarack in nearly clear patches; the shrubs are mainly Labrador tea, Ledum groenlandicum Oeder, small cranberry, Oxycoccus oxycoccus (Linn.) MacM., lambkill, Kalmia angustifolia Linn. and the pale laurel, Kalmia glauca Ait.; the herbs are mainly the universal sphagnum, the cotton grass, Eriophorum sp.?, the sundew, Drosera rotundifolia Linn., the swamp five-finger, Comarum palustre L., and a variety of orchids. The more strictly aquatic plants will be mentioned in connection with the situations in which they grew, and where studies were made of the insect fauna. But I should not omit to mention in passing that the exposed banks by every roadside were covered with mats of


Map 2 Saranac Inn and immediate vicinity

*Lakes and ponds:* 1 St Regis pond; 2 Grass pond; 3 Lake Clear; 4 Little Clear pond; 5 Little Green pond; 6 Bone pond; 7 Rat pond; 8 and 9 Little Bog ponds; 10 Upper Saranac Lake
*Places:* *a* Saranac Inn railroad station; *b* Adirondack hatchery; *c* the sawmill; *d* the Inn

mosses, mainly Polytrichium, and bunchberry, Cornus canadensis Linn., and the latter were very pretty, when covered with white bracts, as in June, or when covered with scarlet berries, as in August.

**Propagating ponds.** Since the three ponds reserved by the state for fish-propagating purposes were the scene of our principal field studies, a few words concerning their character may best be said here.

*Bone pond* is quite small, as our map will show, is hidden in deep woods, and is accessible only by a "carry" from Little Green. It has gently sloping banks round about, there being no outlet, the hemlocks of the woods come down near to the shore, and there is not the usual fringe of tamaracks outside the sphagnum moss which thinly fringes its banks, but the sphagnum is grown full of lambkill and other small heaths. The sphagnum ends in shallow water and is followed by a zone of sedge, Dulichium arundinaceum (L.) Britton, and manna grass, Panicularia sp.? In the deeper water, but not forming a continuous zone except for short distances, are stretches of yellow water lilies, Nymphaea advena Soland., and a species of bur reed with very long stem and leaves, the latter not rising from the surface, but lying flat and directed generally off shore, Sparganium simplex angustifolium (Mx.) Englm.? In the more open places along shore a species of pipewort, Eriocaulon septangulare Wither., was observed growing abundantly, and extending out into deeper water by a succession of stolons, which rooted readily to the white sand of the bottom. Among these lay loosely small masses of moss and filamentous algae. In such places the sieve net brought up from the bottom, where they were beyond view and almost beyond reach of the net, besides the pipewort, moss and algae, great quantities of empty caddis fly cases of the species described in the following account of that group by Mr Betten as no. 2, p. 572, and also the loose, flocculent cases of blood worms (larvae of gnats, Chironomidae); but the larvae of the gnats themselves were not found except in the stomachs of the brook trout which lived in this pond, and in these they were abundant. The burrowing nymphs of dragon flies, Gomphus, were also common here, where they burrow along under the thin layer of silt that covers the sand. They seemed to escape the trout. Among the sedges and grasses nearer shore other dragon fly nymphs and caddis fly larvae were also abundant.

This pond was farther from headquarters than were any of the other situations in which we planned field studies. We did not visit it till

August, and we went to it then only because it offered an exceptionally good opportunity for the study of the insect food of the brook trout.

*Little Green pond* is a beautiful sheet of water half a mile long and nearly as wide, with steeper banks that are nearly destitute of aquatic vegetation, excepting in the little bay on the north shore, and with a bottom of clean white sand. The vegetation of the bay is somewhat similar to that of Bone pond, with the addition of the white water lily, Castalia odorata (Dryand.) Woodv. & Wood. Wintergreen, Gaultheria procumbens Linn., and twin flower, Linnea borealis Linn., and the pretty little Dalibarda repens Linn., as well as big tufts of the lichen commonly known as "reindeer moss," occupy the dry and abruptly sloping south shore. Little Green is not a trout pond. Frequent plantings of fry have resulted in nothing. Little collecting was done there, for it seemed very barren of insect life.

*Little Clear pond* (pl. 1, 2) is nearly a mile and a half long, a mile wide, and is said to be in places more than a hundred feet deep. It is worthy of a more pretentious name. Owing to irregularities of contour, it has a very long shore line, that varies in character according to the inclination of the adjacent slopes. Conditions have been somewhat disturbed here within recent years by the building of a dam at its outlet, that has raised the water several feet, and caused it to encroach on the surrounding timber, which now stands dead along the shore. Aquatic shore vegetation is not abundant except in a few places. Two places were selected in Little Clear for more or less regular collecting, the bay in Blueberry island near the west shore, and the outlet.

Blueberry island is a small sandy spit of burned-over land, now covered with a thin growth of poplar trees, with broad mats of moss and lichen, with extensive clumps of blueberries, and with other clumps of Labrador tea overhanging its shores, specially in the bay. The banks are strewn with decaying trunks of fallen hemlocks, and in the narrow channel between the island and the hill to the westward dead trunks are still standing in water of considerable depth. The water is shallow for a little distance in the bay, and contains a sparing growth of aquatics, such as yellow and white water lilies, sedges, and cat-tails. Not a great many species of insects were collected from this bay, but some of these were exceedingly abundant; as, Chauliodes rastricornis, and species of Gomphus and of Tetragoneuria.

The outlet of Little Clear pond offered considerable variety of situation in small compass. Its east shore was strewn with logs so thickly as to be difficult of access with a boat except next the lake, where was a

low hummock of land covered with cat-tails. Behind this hummock was a shallow stretch of water in which we did some most profitable collecting. The bottom here had once been dry land, and was covered mainly with fragments of bark and twigs, but it was the home of numerous caddis fly larvae, particularly those with cases of stick chimney, or cobhouse type, and of the nymphs of the fine May fly, Siphlurus alternatus Say. The west shore of the outlet was more accessible; and, though collecting along it was not easy because of the abundance of brushwood to entangle a net, it yielded a great deal of most valuable material, particularly dragon fly nymphs. My only specimens of the nymphs of the two beautiful species, Cordulia shurtleffi Scudd. and Leucorhinia glacialis Hagen, were obtained along this shore in a sheltered place.

Through the outlet there flows an imperceptible current, which may be responsible for the presence of two interesting plants there which were not observed elsewhere, the water shield, Brasenia peltata Pursh, and shining river weed, Potamogeton lucens Linn. Of the latter there was a bed directly in the channel, and, passing over in a boat it was delightful to look down into the depths of the clear water, at the long graceful sprays of shining lutescent leaves. A species of bladder wort, Utricularia, was not uncommon in the shallow water behind the cat-tail hummock, and two species of shinleaf grew there at the shore, Pyrola secunda Linn. and P. elliptica Nutt.

Little Clear creek (pl. 3–6) will be discussed below in connection with the account of the special studies made of the life of its waters.

*Bog ponds.* Of the numerous small ponds in the vicinity of Saranac Inn, hidden in the woods and fringed with a typical floating border of bog moss, we collected extensively at but one—the one a quarter of a mile southwest of the station and south of the track—and visited but one other, about as far east of the station and north of the track. Of the former only I will speak here; the other was very similar.

This little pond (pl. 7) was a woodland gem. The picture of it presented herewith gives but a poor idea of it; for the fine coloration of fringing vegetation, of forest background, and of water and sky are necessarily absent from the picture. It was a peculiar place to collect in, being difficult of access, and very difficult to collect in when reached; but it was conveniently near at hand, and was peculiarly attractive on account of the many beautiful and interesting plants and insects found there. Its vegetation (pl. 8) showed a beautiful zonal distribution. Farthest out

was the zone of the very abundant yellow water lilies. Next came a very broad zone of sphagnum, floating at its outer edge over water 5 feet or more in depth, with here and there a detached and floating island. This zone was fairly sprinkled over with pitcher plants, Sarracenia purpurea Linn., and with a succession of pretty orchids, Limodorum tuberosum L., Arethusa bulbosa Linn., Habenaria sp?, while a few clumps of lambkill and tufts of cotton grass were scattered about. Back of the sphagnum was a thin fringe of pale green tamaracks, while dark hemlocks of the forest stood close behind, and in the pools in their shadows nestled beds of native callas. Numerous fine dragon flies and a few large caddis flies and the handsome larva of some, to me unknown, diving beetle were the principal insects observed there.

## Objects and results

This station, being located in the midst of a region whose aquatic insect fauna had scarcely been studied at all, offered a wide choice of field operations. Being established solely for the study of aquatic insects, and in this respect unique among field stations, it lacked the advantage accruing from the simultaneous study of other forms of aquatic life, but offered opportunity for concentration on some of the problems of aquatic entomology. The following objects were had in mind, though it was realized from the beginning that little would be done with some of them, and that any one of them might have been made to occupy our time profitably: 1) to increase the state museum collections; 2) to increase our knowledge of the aquatic insect fauna of the Adirondack region; 3) to study the place of aquatic insects in natural societies; 4) to study the reproductive capacity of insects; 5) to study the habits of aquatic insects; 6) to study the food relations of insects, fishes and other aquatic animals; 7) to study the life histories of aquatic insects.

**Additions to the state museum.** Our collections of specimens were so numerous that the attempt made at first to keep some record of the number and kind of specimens was early abandoned. When hundreds and even thousands of specimens were being collected every day, the enumeration of them would consume time that was greatly needed for matters of more importance. Miscellaneous collections were made by sweeping vegetation with a net, and by trap lanterns set at night when the rain ceased long enough to permit these operations, and the material thus obtained was sent while fresh to Albany to be prepared there for the cabinet. On warm, still, rainless nights the lanterns attracted from the surrounding woods a very large number and variety of moths, which have been preserved, but not studied as yet.

Special collections were made of aquatic insect species hitherto insufficiently known, of which not a few species known only from a few poor specimens appeared at Saranac Inn in great numbers; and we took occasion to gather good series of specimens of such, and also of a few new species which were no less abundant.

The most valuable collections were those of life history material. All that is described in part 3 of this report as coming from Saranac Inn has been added to the state museum; and so important is this material that future monographers in several groups will find it very desirable to consult the collections at Albany.

**Aquatic insect fauna of the Adirondacks.** All that has been written on this subject is comprised in a few short paragraphs in two papers by Dr Lintner,[1] in a few isolated desciiptions of Adirondack species, like that of Simulium pictipes, from Ausable river, by Dr Hagen,[2] in a record by Dr Calvert[3] of a few dragon flies collected at Lake St Regis by J. Percy Moore in 1890, and at Keesville by W. Sheraton in 1894, and in rare locality references in other lists. The Adirondacks are not less interesting entomologically than the White mountains, which have been the resort of New England entomologists for half a century.

The following lists, while not even pretending an approximation to completeness (excepting, perhaps, the suborder Anisoptera of dragon flies) add a considerable number of species, not hitherto known to occur within our fauna; and also, a small number of interesting new species. Of these I have described three species and a variety under the following names: Leuctra tenella; Sisyra umbrata; Climacia dictyona; Gomphus descriptus var borealis.

I have also described the male of the interesting pygmy May fly, Baetis pygmaea Hagen, hitherto known from a fragment of a single female specimen, and the female of the beautiful dragon fly, Leucorhinia glacialis Hagen (pl. 10).

Mr D. W. Coquillet has described at my request two new genera and species of Diptera (*see* p. 585 and p. 586); and W. H. Ashmead has described five new species of parasitic Hymenoptera (*see* p. 586) and Mr A. D. MacGillivray, two new species of sawflies (*see* p. 585).

As the region about Saranac Inn differs considerably from most localities in the Adirondacks, as stated above, its insect fauna will doubtless

1 Lintner, J. A. Collections in the Adirondack region. 5th rep't N. Y. state entomologist, 1889. p. 281-86.

——— 10th rep't p. 376-77.

2 Hagen, H. A. A new species of Simulium with a remarkable pupa case [Simulium pictipes]. Bost. soc. nat. hist. Proc. 1879. 20 : 305-7.

3 Calvert, P. P. Odonata of New York state. N. Y. ent. soc. Jour. 1895. 3:39-48. Additions, 1897. 5:91-95.

be found likewise to differ. It has an abundance of dragon flies and caddis flies and of certain Diptera, while certain other groups, notably the stone flies, which require more rapid and rocky streams, are not well represented.

**Place of insects in natural societies.** A very little was done by us in the study of this subject, but that little constitutes part 2 of the present report.

**Reproductive capacity of insects.** But one thing was attempted under this head, and that was the determination of the number of eggs laid by individuals of a number of species, by means of the examination of the ovaries of newly transformed females. This undertaking at once revealed some interesting biologic facts, which might, perhaps, have been inferred in advance, and which may be known, though I have not read of them. These may be stated as follows.

1 In certain insects (as May flies, caddis flies, gnats, etc.) which lack functional mouth parts, and whose adult life is very brief, the eggs are well developed at transformation, and may readily be counted, the difference in size between the developed eggs and the egg rudiments which will not develop being very marked.

2 In other insects (such as the larger dragon flies) the eggs are very immature at transformation, and it is impossible to determine how many of the egg rudiments present at that time will develop into eggs. In other words, the time of the maturing of the eggs is related to the duration of the adult life, and to the amount of food taken during adult life.

Having read that the larger dragon flies of the gomphine group live as imagos but a week, I was surprised to find that the eggs of a newly transformed female of Hagenius brevistylus were so immature as to be scarcely recognizable; but I have since observed that there is in this and in many other large gomphine species an interval of about a month between the period of transformation and that of oviposition. I am inclined to think that the dragon flies which have been kept successfully only a week in confinement have died of starvation, and that in any case the length of imaginal life is not fairly determined so.

The few counts successfully made by us from insect ovaries will be found under the discussion of the species on which they were made.

**Study of the habits of insects.** What animals do has always been an interesting subject of inquiry, and probably will always be so. A knowledge of the habits of animals has its own peculiar culture value, now generally recognized. It has a higher scientific value,

also, than specialists have always been willing to admit. It has a paramount economic value also, for it forms the basis of nearly all intelligent economic procedure. We do not yet know how the teeming aquatic life of our streams and lakes and ponds may be manipulated as terrestrial life is manipulated to serve human needs, but this we may learn in due time, and, when we have learned it, the accurate knowledge of the habits of aquatic species of insects will be as necessary then as such knowledge of economic terrestrial species is now.

The following pages contain new observations on the habits of many species — occasionally on groups of species. These will be found under the accounts of the groups and the species in part 3 of this report.

**Food relations of insects and fishes.** It was planned from the beginning that we should study fish food, if the opportunity offered for making a real contribution to the present knowledge of that subject. When, through the courtesy of the state fish commission, we were given working quarters in the Adirondack hatchery, we were the more desirous of attacking some of the problems which scientific fish culture needs to have solved; what problems, it was at first a little difficult to decide.

In the culture of all animals there are two principal objects to be sought: 1) protection for the young, and 2) forage. Past triumphs of fish culture have come from the mastery of the difficulties in securing the first of these, the second has scarcely been seriously undertaken. While extensive food studies have been made by Prof. Forbes and a number of others, from which we have learned in general terms what fishes eat, still there is hardly a fish of which we may say we know what species it eats, at what age, at what season, in what situations, with what choice of food. And so little are the essential features of good foraging ground understood that each planting of fry in a new place is still largely an experiment.

So it seemed to me that any new study of fish food should include the study of the feeding grounds, feeding habits, choice of food offered, and conditions that make for the continuance and possible increase of the food supply. The two smaller propagating ponds at Saranac Inn, Bone and Little Green seemed to offer an excellent opportunity for contrasting conditions relative to these points. Bone pond has been well stocked with brook trout for some years, while Little Green, after numerous annual plantings, has remained as barren of trout as ever.

Through the earlier part of the season some random collections of food were made from trout caught in gill nets set for suckers; but not till August was there opportunity to make the studies outlined above, and

then our efforts met with interference which made their successful prosecution impossible. Before they were abandoned, however, the stomachs of some 27 brook trout were obtained, and their contents (consisting almost wholly of insects), cleaned and preserved, are now part of the state museum collection. The records of the numerous insects collected during these few days about the shores of Bone pond will be found under their respective species in part 3 of this report, and a brief account of the vegetation, above in the introduction. A random report on the fish food there collected may yet be made from the material I prepared, but it will of necessity lack the features which I counted most essential, unless farther study be made at the pond itself.

Bullfrogs were common in Little Clear creek, and I collected the stomach contents of 25 of them. Lack of time is the only reason why they have not been studied, and are not reported on at the present time.

**Life histories of insects.** One of the first decisions made with respect to station work was that no greater service could be done for aquatic entomology, pure or applied, than adding as opportunity offered to present knowledge of insect life histories. So long as the species can not be recognized in their immature stages, little progress is possible in food studies, or in quantitative studies of any sort. To this absolutely necessary preliminary work, therefore, much the greater part of our time was given.

We were able to work out more or less completely the life histories of about a hundred species of aquatic insects, immature stages of most of which are described in part 3 of this report. Those who have done life history work will not need to be told that this work occupied rather fully the available time of our short session.

In order to make part 3 serviceable to teachers and students, I have filled it with keys and tables for determining the orders, families, genera and species of immature stages of aquatic insects, and have illustrated these with special figures explaining the terms used. The several orders will be found to have received very unequal treatment, because we wished to add chiefly to the knowledge of the things least known. For this reason the larvae of Diptera and Coleoptera received much less than a fair share of attention; for they are already much better known than are the larvae of the other orders treated.

More dragon flies than anything else were reared. There are two reasons for this: Saranac Inn is a splendid locality for dragon flies, and I have been rearing dragon flies for a number of years and have learned how to do it. With slight additions from my former breedings, I have

been able to give in part 3 an account of the dragon flies (suborder Anisoptera of Odonata) which is almost a monograph of the New York species of that group.

But two species of stone flies were seen at Saranac Inn. Both of these were reared, and the descriptions of their nymphs, published herewith, appear to be the first to be printed for American species.

I have been able to rear representatives of all the New York genera of May flies, and present in part 3 a key for the determination of the nymphs of the same—apparently the first key to be published for American forms.

In the Neuroptera, with its two families having aquatic genera, I have been able to straighten out a tangle in the Sialidae, and to report the discovery of larvae and pupae of two genera of Hemerobiidae. These two are both new species of spongilla flies, representing two genera whose larvae live on fresh-water sponges. Entomologically, their discovery was one of the best things of the season. Our account of the aquatic Neuroptera is thus considerably more complete than any that have hitherto appeared.

Mr Betten occupied himself during the intervals of routine operations with the study of the habits and transformations of the caddis flies. He has written the account of this order in part 3. He collected many specimens in all stages, and reared four species representing as many genera. His descriptions seem to be the first that have appeared for American larvae. It is a matter of regret that specific determinations could not be had for more of the material in this little studied group. He has prepared a table for caddis fly larvae, compiled from the descriptions of European writers and verified, so far as possible, on his own material, and while it is tentative and incomplete, it will doubtless serve a temporary purpose.

Aquatic larvae of flies and beetles were abundant at Saranac Inn, but there was little time available for their study after attending to the others mentioned above. A few of the more interesting ones were reared, however, and will be found described in part 3. The three bred Diptera there described make an interesting addition to our knowledge of the larvae of that order.

**Apparatus and methods.** Little need be said on this head. We used the insect nets, cyanid bottles, setting boards, pins, and preservatives used by all collectors; but our main stay in aquatic collecting was the sieve net[1], which is shown in use in plate 4; leaning against a tree in

[1] Described and figured in part O of U. S. nat. mus. Bul. 39, p. 4.

plate 5. On the sandy bottoms of these quiet waters it was specially advantageous. Extensive use was made of white wash bowls, soup plates and saucers in the examination of our catch. We habitually placed teneral specimens of most orders, when found in the cages newly transformed, in paper bags to await the maturing of their colors.

For rearing purposes, the screen cage, a simple cylinder of wire screen with a loose cover (described on page 7 of the above mentioned bulletin and shown in operation in plate 5) was most useful. The larger cages of this sort were set down in the sand of the bottom of the creek; smaller ones were set in the hatchery troughs. These, of course, needed a bottom, which was supplied by inserting a piece of cloth laid over an open loop of spring wire; the wire when released holding the cloth tightly against the sides of the cage. A still farther modification of this cage consisted in making it smaller, and of fine brass screen, and attaching cork to its sides to float it. Mr Betten made a very good egg-hatching cage out of it by sealing a watch glass in the bottom of it with paraffin, and attaching the cork floats. The eggs were thus kept in flowing water, but could be at once removed to the stage of the microscope without disturbance.

I devised for our work at Saranac Inn another type of floating cage that proved so generally useful for minute insects, and was so easily and rapidly constructed that it may be worth while to give a description of it. The accompanying figure shows its construction in the main. With the five little pieces of wood (which should be cut from dry pine) at hand, a cage of this sort can be put up and ready for use in 10 minutes. The cloth is attached to the wood by means of paraffin, which is melted and applied with a brush. The loose end of the cloth is attached, and the door closed by means of a rubber band stretched between two tack heads over the convex upper edge of one of the wooden side strips (fig. 1). This sort of cage was most successful with small Diptera, but not with small May flies, such as Caenis; for these would invariably fall into the water and die at once on transformation.

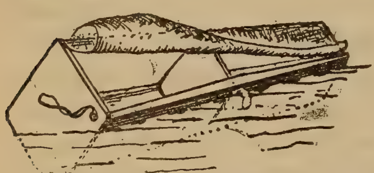


Fig. 1 Floating cage, designed for rearing small Diptera

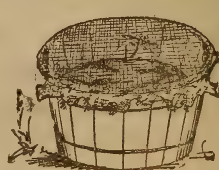


Fig. 2 A homemade cage which can be used successfully for rearing insects that live in standing water. Wooden kit with covering of netting tied on

The trap lanterns we used (pl. 4, 5) were also very simply constructed. The idea of them, however, was borrowed from some lanterns I found my

friend, Dr Westcott, using. The lantern part is of the "search light" type to be found on the market, with large parabolic reflector having projecting edges. The trap part consists of a circular flaring band of tin, whose slope continues that of the edges of the reflector, inside which it is pushed and fastened. It has two transversely placed sheets of wire screen within it, arranged as shown in the accompanying figure, and on the lower side within the trap there is an open, detachable cup to hold the cyanid of potassium. It is easily managed and very effective, and the specimens are in the main obtained in good condition. The lantern of the markets has many advantages in the way of conveniences over lanterns of home construction.

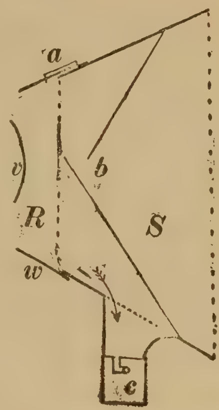



Fig. 8 Sectional diagram of lantern trap
*R*, edge of lantern
*v* the globe
*w* edge of parabolic reflector
*S*, the trap
*a* catch for attachment to reflector
*b* the entrance between two sheets of screen
*c* detachable cyanid cup

**Assistance in preparing this report.** At the conclusion of my work at Saranac Inn, I went to Cambridge Mass., where, through the courtesy of Mr Samuel Henshaw, I was allowed to spend several weeks determining the specimens I had collected, by comparison with specimens in the museum of comparative zoology. During this time Mr Henshaw showed me many kindnesses and took the trouble himself to determine the names of a number of species. I am also under special obligation to Mr D. W. Coquillett and Mr William H. Ashmead, of the U. S. national museum, for the study and determination of numerous Diptera and Hymenoptera respectively, and for the descriptions of new species sent me by them to be published as a part of this report. I am indebted, also, for determinations, to a number of other gentlemen, as follows: Trichoptera, Nathan Banks; Orthoptera, Dr S. H. Scudder; Homoptera, Prof. Herbert Osborn; leeches, Dr W. E. Castle and Dr J. Percy Moore; mollusks, Frank C. Baker; an entomostracan, Prof. E. A. Birge.

The colored plates have been made by L. H. Joutel. The figures of Trichoptera are by Mrs J. H. Comstock. Those of Diptera, Plecoptera and Ephemerida are by Miss Maude H. Anthony. Those of Odonata are drawn by myself. The figures made from photographs taken by other persons than myself, contain the proper acknowledgment in their legends.

*Part 2*

## LIFE OF LITTLE CLEAR CREEK

This tranquil little stream (pl. 3), once famous for its trout fishing, traverses the hatchery grounds, and disappears in the woods below under a canopy of overarching alders. It leaves the pond at present by a little artificial fall, runs through a big, tubular iron culvert under the railroad, tumbling over a little bed of stones at the end of the culvert, and then traverses a narrow bit of brookside meadow, bordered by spring bog full of balsam trees. Then it enters the fish ponds. Passing the hatchery, and all the fish gates, it is free again for a little open space before entering the woods below. From the pond to the woods below the hatchery is less than a quarter of a mile; and in this short space the following studies were made.

In the undisturbed portion of this course the brook glides alternately over beds of rippled reddish sand or percolates through tangled mats of river weed, Potamogeton, and stonework, Nitella, or clumps of bur reed, Sparganium. It has an average depth of perhaps a foot, and a width of about 10 feet. Its depth varies very little with the weather, a continuous downpour of rain for days raising its level but a few inches.

In the edges of the woods were seen scattering stemless lady's slippers, and banks of that dainty little favorite of Linnaeus, the twin flower, while the star flower and the bunchberry and the yellow Clintonia and the red elder berry made these places bright in June with their flowers and in August with their brilliantly colored fruit.

From this little strip of water we did more or less collecting every day of the session. While we thus gained some general information as to what the stream contained, we were desirous of making our knowledge more exact by quantitative studies, for which unfortunately our breedings, requiring constant attention, left us very little time. We did, however, make quantitative studies of the animal life of two little patches of the creek, made a count of the cast skins of dragon flies left along a strip of the bank, made qualitative studies of the insect life of the ripple below the bridge, and of the hatchery pipes and troughs, and made some scattering observations of more or less interest, which will constitute the subject of this chapter.

**Quantitative studies.** These were made from two patches of Little Clear creek, each approximately 15 square feet in surface area. They do not include the animals that slipped through our nets, the

coarsest of which had a mesh of about 2.5 mm square (10 meshes to the inch). The method was the same for both: the plot was staked out; the vegetation was swept with an air net down to the water line for its aerial forms of life; it was swept again with a water net for its aquatic population; it was then pulled up by the roots and piled in pails and examined a handful at a time in a bowl of clean water, having all the animal life separated from it; the soil of the bottom was then scraped up and sifted for a depth of two or three inches. The material was very quickly gathered up from the plot selected, but the separation of the animal life from the plants and débris was a whole day's work for two or three persons, to say nothing of the time necessary for studying the animals later. These studies, though time-consuming, always yielded the information sought as to the relative numbers of the several species present, and were profitable, also, in quite another way. The careful examination of the situation which they necessitated always revealed the presence of a number of species not found by more superficial collecting methods, and these were not always the smaller species.

*First plot.* This was in the creek just below the hatchery. The site is shown in plates 4 and 5. The plot extended from the edge of the current in open water 12 to 15 inches in depth, to the bank, a distance of about 5 feet, and a strip 3 feet wide was selected. Two views of it from opposite sides are given in the plates, and its exact site is indicated by the position of the sieve net in plate 4, and is occupied by the cage in the foreground in plate 5. The collections were made July 10. The water was about 3 inches deep at the bank, and descended somewhat regularly toward the current side. Over nearly the whole of the area there was an abundant growth of aquatics, most abundant among which was a species of matted, submerged Potamogeton, intermixed with a variety of filamentous algae, and a little Nitella. The plants which appeared above the water were water-cress, water-speedwell, and a thin grass which I took to be a species of Leersia. There was no bur reed growing in this plot.

The following animals were taken from this plot.

*Vertebrates*

1 full-grown bullfrog, Rana Catesbiana Shaw, whose stomach contained: 7 full grown snails, Physa heterostropha Say; 1 dragon fly, ♀ Calopteryx maculata Beauv.; 1 Crane fly (undetermined); 1 Scarabaeid beetle; 1 female winged carpenter ant; 1 Syrphus fly (apparently one of the smaller members of the genus Syrphus); 1

caddis fly (teneral imago; undeterminable); 1 water skater, Hygrotrechus sp.?, and fragments of a number of others; 1 small bullfrog tadpole; considerable sand intermixed with fragments of Potamogeton leaves; 1 Entomostracan (undetermined)

3 grown bullfrog tadpoles

1 young green frog, Rana clamata Daud. The stomachs of the tadpoles and of this frog were empty

1 small salamander, probably an Amblystoma

1 long-eared sunfish, Lepomis auritus Linn., whose stomach contained: 34 little snails, the largest not over 1.5 mm long, apparently of the genera Physa and Limnaea; 12 larvae of gnats (Chironomidae), 2 Chironomus sp.? and 10 Ceratopogon sp.?; 1 larva of Chauliodes sp.? in fragments

*Mollusks*

305 snails, retained by our nets, not counting innumerable smaller ones, which fairly covered some of the plants. The 305 were:

292 Physa heterostropha Say

13 Limnaea desidiosa Say

35 small clams, Sphaerium similis Say

*Leeches*

6 specimens 2-4 inches long of Haemopis (Semiscolex) grandis Verrill

A large number of minute glossiphonids, the counting of which was not undertaken

*Insects*

The following were taken with a sweeping net from above the surface of the water

DRAGON FLIES

1 Aeschna sp.?, probably constricta Say, found transforming

1 Ischnura verticalis Say ♀

1 Lestes unguiculata Hagen ♂

2 Argia violacea Hagen ♂ and ♀

1 Nehallennia irene Hagen ♀

BUGS

43 water skaters, Hygrotrechus sp.? (A greater number got away)

2 Helochara communis Fitch

20 Cicadula sexnotata Fall

1 C. divisa Uhler

7 Liburnia pellucida Fabr., of which two were females, one macropterous, and one micropterous

1 Chermes sp.? (apterous)

3 Aphids (undetermined)

1 Lygaeid (undetermined)

### FLIES, AND OTHER DIPTERA

65 Hydrellia scapularis Loew. A number of other little Muscidae, some of them apparently of different species, escaped

1 crane fly ♀ (undetermined)

1 mosquito ♀ (undetermined)

3 gnats of three species (undetermined)

### MISCELLANEOUS

1 Psocid, Peripsocus madidus Hagen

1 Anthicid beetle, Notoxus anchora Hentz

8 parasitic Hymenoptera: Telenomus longicornis Ashm[1]. 1 ♂; Brachystropha quadriceps Ashm.[1] 1 ♂; Rhizarcha astigma Ashm.[1] 1 ♂, 3 ♀s; Aphidius nigripes Ashm.[1] 2 ♂s

The following insects were taken from the water.

### DRAGON FLY NYMPHS

4 Aeschna constricta Say of various sizes, one full-grown

7 Cordulegaster maculatus Selys

3 Gomphus scudderi Selys

6 Gomphus spicatus Hagen

2 Ophiogomphus aspersus Morse

2 Basiaeschna janata Say

2 Sympetrum assimilatum Uhler

### MAY FLY NYMPHS

2 Hexagenia variabilis Etn.

5 Ephemera varia Etn.

3 Ephemerella excrucians Walsh

5 Caenis diminuta Walker. These nymphs are so hard to find among the stems to which they cling very closely, that more were probably present but not seen.

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[1] Described on p. 586–88.

CADDIS FLY LARVAE AND PUPAE

15 Molanna cinerea Hagen

8 Polycentropus lucidus Hagen

2 Halesus no. 1 (*see* p. 567)

2 Halesus no. 2 (*see* p. 568)

3 Halesus no. 3 (*see* p. 569)

13 unclassified . . . 43 in all

DIPTEROUS LARVAE AND PUPAE

3 Sepedon fuscipennis Loew

1 Bittacomorpha clavipes pupa, probably from the farthest point in shore

7 Simulium venustum Say

8 Tabanid larvae (undetermined) from the bottom in the edge of the channel in open water

1 crane fly pupa (undetermined)

107 gnat larvae (Chironomidae: all undetermined) of four species

Numerous minute Ceratopogon? larvae were observed in the algae associated with still more numerous Limnicolous oligochaetes.

*Second plot.* The second plot selected for study was in the upper part of the hatchery grounds, just below the railroad bridge. It was a strip across a bed of bur reeds (shown in the foreground of plate 3) and was similar in form and about equal in area to the preceding. Collections were made precisely as before, but the conditions in the plot were somewhat different; the water was of about the same depth, but there was more of a current flowing through the bur reeds. Potamogeton and Nitella and filamentous algae were perhaps a little less abundant in the water here, specially the algae. The date was July 27.

The list for this second plot is a short one, in species, if not in individuals. It is as follows:

1 bullfrog, Rana catesbiana Shaw

1 crawfish (undetermined)

MOLLUSKS

13 snails: 11 Campeloma decisum Say; 2 Limnaea desidiosa Say

245 clams, mainly Sphaerium simile Say

117 CADDIS FLIES

27 Molanna cinerea Hagen

22 Hydropsyche sp.? (near phalerata) Hagen (*see* p. 566)

17 Polycentropus lucidus Hagen
8 Halesus no. 1 (*see* p. 567)
10 Halesus no. 2 (*see* p. 568)
16 Halesus no. 3 (*see* p. 569)
17 unclassified

260 BEETLES

Donacia emarginata Kirby, of which two were adults, 152 were inclosed in puparia attached to the bur reed roots, and a few were free larvae. Since several species occurred about the creek, it is by no means certain that all these belonged to the single species named.

25 DRAGON FLY NYMPHS

2 Cordulegaster maculatus Selys
4 Aeschna constricta Say
4 Gomphus exilis Selys
5 Ophiogomphus aspersus Morse
5 Argia violacea Hagen
5 Sympetrum assimilatum Uhler. Of this species 7 additional specimens were picked from the stems above the water in transformation; but one other insect specimen (a stone fly, Leuctra tenella) was found above the water.

10 MAY FLY NYMPHS

1 Ephemera varia Etn.
4 Ephemerella excrucians Walsh
5 Baetis pygmaea Hagen

8 DIPTEROUS LARVAE AND PUPAE

2 small crane fly larvae (undetermined Tipulidae)
4 horsefly larvae (undetermined Tabanidae)
2 mosquito pupae (undetermined)

Comparing now the lists made from the two plots we observe some striking differences. Those that appear in the number and variety of aerial forms taken in the first plot, and the paucity of them in the second, may be due mainly to weather conditions: the first plot was worked on a dry, sunshiny morning; the second, on a partly cloudy morning after rain. The plots agree in that their miscellaneous plant feeders were mainly mollusks and caddis flies. Mollusks seem to constitute a larger bulk than any other single group. Snails were found in the stomachs of frog and fish, and are known to be the food of horsefly larvae (Tabanidae). There are certainly snails enough in the creek to justify the extraordinary abundance of horseflies in this vicinity.

The plots were strikingly unlike in that there were fewer species in the second, fewer dragon fly and May fly nymphs and dipterous larvae. They differed farther most strikingly in the kind of mollusks present: the Campeloma decisum of the second plot was absent from the first; it is common in the pond above. The long-horned leaf beetles, Donacia, of the second plot were a special feature which belonged with the special habitat furnished by the bur reed growth. Two photographs, reproduced in plate 9, show these insects in their natural positions on the plant.

These are fragments—mere fragments—of real knowledge of the life of this stream. While not without interest in themselves, they seem to me chiefly valuable in their suggestiveness of possible knowledge to be gained by farther application of these methods.

**Count of dragon fly exuviae.** In the midst of the hatchery grounds there was a fish pond, made by impounding the creek, with its eastern side boarded up to a hight of 15 to 20 inches above the level of the water, for a distance of perhaps 20 yards. The boards were rough, and suited dragon fly nymphs very well as a place to transform. It was an exceptionally favorable place in which to learn something of the numbers of dragon flies to emerge from a given water area; for the cast skins were all left in plain view. The other bank was not boarded, and while the cast skins appeared to be about as common there, one could not be sure of finding all of them. A view of this pond, looking up stream, is presented in plate 6.

Conditions here were right for determining the yield of this strip of water in dragon flies of those species whose period of transformation falls entirely within the last three weeks of June at Saranac Inn. I do not say half the yield, because it seems fair to presume that half were on the other bank, where their discovery was not so easy. Nymphs when ready to transform are blind, and wander about till they find a bank, showing no preference as to which bank it is. These time limits are taken because they are the only narrow ones that will include the entire transformation period of a considerable number of species.

I found quite a number of these skins already clinging to the boards on my arrival June 12, for the season for transformation for some of these species was already at hand. It appears fair to assume, however, that I obtained practically all the skins that had been left there, because they had apparently not been disturbed at all; they stick very tightly, so that moderate winds and even rain do not quickly dislodge them. The weather previous to my arrival had been clear and calm, and the season of trans-

formation was certainly only opening. I collected all that appeared after that daily till the end of June, at which time all the species for which I thought such counting practicable had ceased transforming for the year. The results of the count are as follows.

82 Gomphus exilis *Selys*
20 Gomphus brevis *Selys*
18 Gomphus spicatus *Selys*
24 Ophiogomphus aspersus *Morse*
11 Hagenius brevistylus *Selys*
7 Cordulegaster maculatus *Selys*
1 Didymops transversa *Say*
1 Tetragoneuria semiaqua *Burm.*
6 Basiaeschna janata *Say*

Intermingled with these were the cast skins of a number of species whose period of transformation was not finished, perhaps, by the end of the month of June; viz Calopteryx maculata Beauv. (12), Argia violacea Hagen (20), Enallagma sp.? (5), Boyeria vinosa Say (3), and Aeschna constricta Say (2).

It is difficult to conceive how so many of the large rapacious Gomphine nymphs can get a living in so small space. I do not believe that, judging by repeated collecting, they were more abundant here than in other basins along the creek. I collected in this same place with a sieve net after this count was ended the nymphs of the next season's brood, and obtained in 15 minutes' use of the net 22 Cordulegaster maculatus, 2 Hagenius brevistylus, 40 Gomphus and Ophiogomphus, 8 Calopteryx maculata and 4 Didymops transversa.

**The life of the rapids.** At the railroad Little Clear creek pours out of the culvert and tumbles over a little bed of stones. This is the only rapids within easy reach from the hatchery. There was no time for a quantitative study of its life, but we studied it as carefully as time would permit.

The most abundant and important animal in the rapids is the black fly, Simulium venustum Say. With the exception of a few Chironomidae which live in the "skin algae", covering the broader surfaces over which the water glides, all the life of the rapids seems to center in the Simulium colonies. These are very extensive indeed, masses of the swaying, dark greenish larvae, or of the yellowish pupae covering the stones over considerable areas.

Plate 15 shows the forms which I found together in this little rapids by the railroad. Simulium is vastly more numerous in individuals than all the other species put together and also more restricted in its habitat. The next in numerical importance would probably be the pygmy May fly, Baetis pygmaea Hagen, though a larger May fly, Heptagenia pulchella Walsh, and a caddis fly, Hydropsyche sp.? (see p. 566) seemed almost as numerous. These three species are probably predatory, feeding on the members of the Simulium colony. The other members of this little society are much fewer. They are 1) a hitherto unknown fly of the family Empididae, Roederiodes juncta Coq., (described post at p. 586) whose larvae crawl about among the Simulium pupa cases, and pupate within empty cases, and 2) the stone fly, Leuctra tenella.

It must be another, earlier species of black fly which makes all the trouble in the Adirondacks with its bites; for this one is quite peaceably disposed. Guides have a saying, that, when the black flies put on their white stockings in June, the trouble is about over. This species has the "white stockings."

I was interested in watching the females of this species ovipositing, and saw the operation very frequently. The place selected is always at the edge of a little waterfall, on a surface that is intermittently washed by the swaying current, and so kept wet (*see* pl. 15). Here the females flock, and pile up great white masses of eggs, which with a little age turn yellowish. Waves dash over them while ovipositing, and often sweep them away, but they at once return to their task.

I do not know what Simulium larvae feed on; but their tentacles seem well adapted for straining plankton from the water that dashes over them.

**The life of the hatchery pipes and troughs.** The life of the pipes is essentially that of the rapids.[1] What is living in the pipes is learned by observing what comes out of them, into the hatchery troughs and into the windows. Simulium, Hydropsyche, Heptagenia and Baetis, were in the hatchery windows throughout the session, often in enormous numbers. Their periods of greatest abundance do not coincide however. The windows were fairly darkened with black flies and caddis flies and the larger May flies, Heptagenia, during the earlier part of the session, while the pygmy May flies did not appear in swarming numbers till the latter part of it. The only member of the Simulium society as portrayed in the plate, which was not observed

1 It appears that the mollusks which get into city water pipes and sometimes cause trouble are forms that normally live in rapids.

to come into the hatchery was the fly, Roederiodes juncta. In addition to these forms, and the green stone fly, Chloroperla bilineata Say, which doubtless belongs with them in its season, there occurred in the hatchery a large number of Diptera of various sorts, and the spongilla flies, hitherto accounted so rare. Fresh-water sponges from the lake above invade the pipes, and the larvae of these flies come in with the sponges on which they live.

On June 19 we collected the contents of one of the supply troughs in the hatchery. It contained more than 125 little fresh-water sponges, averaging the size of peas, from which were picked seven spongilla fly larvae, nine amphipods (undetermined), one entomostracan, Epischura lacustris Forbes, about a dozen each of two species of May flies, Heptagenia pulchella Walsh and Ephemerella excrucians Walsh, a large number of black fly larvae, a few Hydropsyche larvae, a few gnat larvae and a number of colonies of rotifers.

Some of the multitudinous gnats in the windows were of the same species that I bred from larvae taken from "skin algae" scraped from the races outside. Horseflies (Tabanidae) were also conspicuous occupants of the windows, but I did not find their immature stages in the hatchery. Possibly these may have come in through open doors and windows, being so active and so abundant outside. The handsome longicorn beetle, Leptura canadensis Fabr., which was not uncommon in the windows during the latter half of the session, certainly entered in this way.

A small number of specimens representing a new genus and species of Stratiomyiidae (described in part 3, p. 585 as Zabrachia polita Coq.) were picked from the hatchery ceiling, while gathering spongilla flies.

Red hydras were exceedingly abundant in Little Clear creek during the first half of our session, insomuch that they fairly covered every trailing stem and leaf in the current, and occupied every available support, even to the backs of the dragon fly and May fly nymphs, one of which would often bear half a dozen or more of them. Then they gradually disappeared, till in August hardly a hydra was to be found. A single blade of Sparganium brought in in June for some eggs of Basiaeschna janata which had been laid in it, bore hundreds of hydras profusely budding, and all of a very distinct red color. An observant employee of the hatchery, Milo Otis, who attends to feeding the fry, informed me that at certain times the water flowing through the ponds is tinged with red from the hydras floating in it, and that at such times the young trout subsist on these, and refuse to eat other food. It would be interesting to

know whether this abundance of hydras always occurs when the trout are newly hatched.

Two fine Diptera belong to the characteristic fauna of Little Clear creek, but do not live in any of the situations we have been discussing. These are the curious phantom fly, Bittacomorpha clavipes Fabr., and our largest crane fly, Tipula abdominalis Say. Both live almost out of the water in very shallow bays filled with red-rotted vegetation and both are very common in such places.

Gomphus scudderi Selys was common in the creek below the wagon bridge, but was not taken above it.

## *Part 3*

## INSECT LIFE HISTORIES

In the following pages there is assumed on the part of the reader such a knowledge of the external parts of insects as is obtainable from the elementary textbook of entomology or of zoology. He should know that the body of an insect larva is composed of successive rings or joints; that the first division is the head and bears the eyes, antennae and mouth parts; the next three joints, bearing the wing and leg rudiments, constitute the thorax; and the remaining joints, often with prop-legs or prolegs under them, constitute the abdomen. External gills are arranged in delicate whitish tufts when in a sheltered position, or, when exposed, are thin plates traversed by delicate air tubes. In addition to these, there are at the sides of the abdomen, longer, paired, simple, pointed appendages, called lateral filaments, which also, when small and delicate, may serve the respiratory function. Lateral filaments, gills (with very few exceptions) and prolegs disappear with the end of larval life, and are absent in the adult insect.

In the immature stages insects differ wonderfully; but there are two types of larvae, which have been distinguished by the degree of difference between larva and adult insect: 1) those called nymphs, which differ but little from the adults in general organization, and when grown transform directly to imagos, without having entered on a quiescent pupal stage; and 2) larvae proper, which differ very greatly from their imagos, having the adult appendages reduced in size or altogether wanting, wings never visible externally, and requiring a quiescent pupal stage, when they have done feeding, before transforming to the imago. These two groups constitute the primary divisions of the table given below. The student will find in Comstock's *Manual for the study of insects*, or in his *Insect life*, or in a number of other books that are not so

good as these, serviceable tables for the determination of the adult insects. We give here a table that will serve for distinguishing the orders in the larval stage. So few relatively of the larvae of aquatic insects are known as yet, that this table must be considered tentative as to its statements of group characters.

In all the following tables and descriptions the characters described and the measurements given apply to fully grown nymphs or larvae except when otherwise expressly stated.

### KEY TO ORDERS OF AQUATIC INSECT LARVAE[1]

*a* Larvae with wings developing externally (called *nymphs* in this paper) and no quiescent pupal stage

*b* With biting mouth parts

*c* With long, filamentous caudal setae; labium not longer than the head, and not folded on itself like a hinge

*d* Gills mainly under the thorax; tarsal claws two; caudal setae generally two.......................................(stone flies) Plecoptera

*dd* Gills mainly on the sides of the abdomen; tarsal claws single; caudal setae generally three........................(May flies) Ephemerida

*cc* Caudal setae represented by three broad, leaflike respiratory plates traversed by tracheae, or by small spinous appendages; labium much longer than the head when extended; at rest, folded on itself like a hinge and extending between the bases of the fore legs (dragon flies and damsel flies) Odonata

*bb* Mouth parts combined into a jointed beak, which is directed beneath the head backward between the fore legs.....................Hemiptera

*aa Larvae proper*, with wings developing internally, and invisible till the assumption of a quiescent pupal stage

*b* With jointed thoracic legs

*c* With slender, decurved, piercing mouth parts, half as long as the body; small larvae, living on fresh-water sponges. Family Hemerobiidae of Neuroptera

*cc* With biting mouth parts

*d* With a pair of prolegs on the last segment only (except in Sialis, plate 29, which has a single long median tail-like process at the end of the abdomen) these directed backward, and armed each with one or two strong hooks or claws

*e* Abdominal segments each with a pair of long, lateral filaments Family Sialidae of Neuroptera

*ee* Abdominal segments without long, muscular, lateral filaments, often with minute gill filaments; cylindric larvae, generally living in portable cases.........................(caddis flies) Trichoptera

1 The Thysanura, or springtails, common on the surface of water, but not living in it are not included in this table. They will be readily recognizable, if collected, by their very minute size, entire absence of wings, mouth parts retracted within the head, and the forked spring beneath the abdomen.

*dd* Prolegs, when present, on more than one abdominal segment; if present on the last segment, then not armed with single or double claws; often entirely wanting

*e* With five pairs of prolegs, and with no spiracles at the apex of the abdomen .............................. (moths) Lepidoptera

*ee* Generally without prolegs; never with five pairs of them; usually with terminal spiracles; long, lateral filaments often present on the abdominal segments ................ (beetles) Coleoptera

*bb* Without jointed thoracic legs; with abdominal prolegs, or entirely legless; in the more degenerate forms, the head is reduced and retracted within the pointed apex of the thorax, no appendages of the imago are visible, and the pupa is formed within the contracted and hardened larval skin (flies, etc.) Diptera

Those orders, on which some life history work was done at our station, are severally discussed below. That some of these, notably the Coleoptera and the Diptera, were slighted, is only too apparent, and no one will be so regretful as we are that no more time could be given to the study of these; but the other orders treated seemed to be in more pressing need of study; and we always had more life history material available than could be attended to by two pairs of hands. A few random notes on the representatives of those orders which received from us no study whatever, will be found grouped together under a final heading.

## Order PLECOPTERA

### *Stone flies*

The stone flies are all aquatic. They frequent rapid streams, and are most abundant in those places where the water dashes over heaps of broken, half submerged rocks. In summer one may often see in such places the projecting top of a rock decorated with the empty skins which the adult stone flies left behind when they left the water and acquired wings. To find the nymphs one need but lift a stone from the water quickly, turn it over and look at it. The flat, closely clinging nymphs will be seen with their legs at full stretch and their claws gripping the rock, or running from one depression to another, seeking to hide.

The nymphs are little known. In this country they have received hardly any attention, which is surprising, considering that they are so easy to collect and to rear, and that they live in places in general so attractive to us. The good angler who has the blood of a naturalist in him is likely to know the species of stone flies, both nymphs and adults, better than does the average professional entomologist. The systematic study of the order is little advanced beyond the point where Pictet left it 60 years ago[1]: his work is still the best textbook of the group to be had.

1 Historie naturelle des neuropteres: perlides. Paris 1841.

The nymphs of stone flies require well aerated water. They can not live in a stagnant pool[1], or in a foul stream. A large number of the smaller species, including the two described below, are entirely destitute of gills. With these the air supply is absorbed directly through the thin skin of the ventral surface. At the ventral sutures one can readily see that the skin is fully permeated by fine tracheal branches. Stone fly gills at their best development are but small tufts of delicate respiratory filaments attached to the ventral surface of the body, oftenest about the bases of the legs, swished about by the motion of other parts, or dependent on the motion of the water for the renewal of the oxygen supply. Nymphs brought in from the brook and placed in a vessel of still water will soon be seen with claws affixed vigorously swinging the body up and down, trying to get a breath under the difficult conditions into which they have been brought.

In two important respects the nymphs of May flies and dragon flies have surpassed those of stone flies in the development of aquatic respiratory apparatus:

1 In developing flat, plate like gills, which offer greater surface for contact with the water;

2 In developing special apparatus for the independent movement of the gills, or for causing currents of water to flow over them.

It is the smaller species that are gill-less. The extent of respiratory surface is in a measure proportioned, 1) to the size of the nymphs; 2) to the condition of the water, whether well or poorly aërated.

It is because of the limitations on the respiratory system of stone-fly nymphs that they are so restricted in their aquatic habitat.

As to the food of the stone flies there have been a number of guesses, but apparently no careful and continuous observations recorded. It is supposed that the nymphs of the larger species eat smaller May fly nymphs, and soft-bodied dipterous larvae associated with them on the rocks; but Benjamin D. Walsh has said that perlid nymphs eat decaying vegetable matter, and that the imagos eat nothing.[2] Here, then, is an opportunity for some careful observer to replace inferences with facts.

The adult stone flies may be collected at almost any season of the year. The little black capnias emerge in winter. They live mainly in small brooks, and are often found in transformation on the edge of the ice. Through the spring months the dusky and grayish little nemouras

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1 I have bred a species of Acroneuria in some numbers from nymphs taken from rotting oak leaves in the edge of an ice pond at Ithaca N. Y.; but the water about the bed of leaves was clear, and could not be called stagnant, since the turbulent Cascadilla creek flows through the pond.

2 Practical entomologist. 2:73.

are emerging; but the larger stone flies, and the paler and green ones are to be looked for mainly in summer.

Stone flies are abundant in most parts of the state of New York. Every rocky stream swarms with them. But about Saranac Inn there are no rocky streams. The creeks flow leisurely over beds of sand or filter through mats of river weed, and are destitute of the stony obstructions which afford suitable shelter for young stone flies. But two of the smaller species were studied there, and these were neither abundant nor very important members of the aquatic fauna. Both live in Little Clear creek and in the pipes which bring water to the hatchery, and both were taken as adults at the hatchery windows. Nathan Banks has published keys to the North American genera of stone flies in the *Transactions of the American entomological society*, 20:328–29; and 26:240–42. The student is referred to these.

### CHLOROPERLA

This genus includes a small number of delicate, pale green stone flies about half an inch long. At emergence they fly to the shelter of green vegetation, and thereafter remain concealed most of the time, returning to the water, perhaps, to deposit their eggs. So far as known, the nymphs which live in clear streams are entirely destitute of gills. C. A. Briggs has recorded a curious habit of the adult male of Chloroperla.[1] Placed in a box, it struck the bottom with its penultimate abdominal segment to make a noise.

## Chloroperla bilineata Say

1823 Sialis bilineata Say, Godman's western quarterly reporter. 2:165 (original description)
1839 Chloroperla transmarina Newman Ann. & mag. nat. hist. (2) 3:87
1841 Chloroperla transmarina Pictet, Perlides, p. 283
1852 Chloroperla transmarina Walker, Cat. neur. ins. Brit. mus. 1:161
1852 Chloroperla picta Walker, Cat. neur. ins. Brit. mus. 1:161
1861 Chloroperla bilineata Hagen, Synopsis Neur. N. Am. p. 30
1892 Chloroperla bilineata Banks, Am. ent. soc. Trans. 19:342 (listed)
1899 Chloroperla bilineata Banks, Am. ent. soc. Trans. 25:200 (included in a key to species of Chloroperla)

This species was taken only in the hatchery. It was already disappearing when we arrived, June 15. A few could be found about the windows each day. Many more dead ones were discovered in the hatchery loft, entangled in spiders webs, or fallen on the window sills,

1 Ent. month. mag. 1897. 33:207–8.

having made their way upstairs, seeking their freedom. They were not observed flying, except from the place of transformation to the window.

Empty nymph skins were, on the contrary, very abundant. There were hundreds sticking to the sides of the hatchery troughs, thickest near the inflow pipe, but some were to be found on all the troughs.

Observing that the season for the species was waning, we lost no time emptying the supply trough and sifting its contents. Thus we obtained two nymphs, one of which was reared.

**Imago.** Length to tip of wings 12 mm; antennae 7 mm more. Setae two thirds as long as the abdomen, hardly surpassing the tips of the wings. Expanse of wings 21 mm.

Color light green. Antennae brownish black, except a small paler part just beyond the base. A broad U-shaped mark on the top of the head, just including the ocelli. A blackish brown stripe each side of the prothorax, darkest anteriorly, continued on the mesothorax, diffused posteriorly. Abdomen greenish, washed with brown dorsally, specially toward its lateral margins. Setae brownish. Legs greenish, a little darker exteriorly and at the tips of the tarsal segments. Wings green; veins very faintly touched with brown.

**Nymph.** Fully grown, measures 9 mm; setae 3.3 mm more.

Body slender, slightly depressed. Head hardly wider than prothorax or than abdomen; the latter a little widened in the middle and a little more narrowed at the posterior than at the anterior end.

Color greenish to pale brownish. Antennae green at base, becoming brownish at tip, stout at base, rapidly tapering. The broad U-shaped mark on the top of the head in the adult is present in the nymph, the base of the U being laterally extended in a transverse band which meets the eyes and extends two angles anteriorly toward the mouth each side. Prothorax with two lateral stripes, darkest anteriorly. Two pairs of small spots on mesonotum and on metanotum between the bases of the wings.

Abdomen with three distinct blackish brown stripes, a median one and two lateral ones, the latter ending on the bases of the setae. Setae stout at base, rapidly tapering; brown at base, becoming paler distally. Legs pale greenish. Ventral aspect, whitish or pale green.

No tracheal gills.

Numerous specimens. Adirondack hatchery, Saranac Inn N. Y. June. Observed till June 21, when the last specimen was taken.

### LEUCTRA

This genus includes the slenderest of stone flies; small, brownish species, with wings closely inwrapping the body on the dorsal side. Mr McLachlan says that the females in this genus carry their eggs on their backs, extruding them from the upturned end segment of the abdomen and pushing them toward the bases of the hind wings.[1]

1 Ent. month. mag. 1865. 1:216.

**Leuctra tenella** Provancher (pl. 15 and fig. 4 and 5)

1878 Leuctra tenella Provancher, Petite faune entomologique du Canada. p. 80[2] (without description)

1892 Leuctra tenella, N. Banks, Am. ent. soc. Trans. 19:343 (cited)

This species was much less common than the preceding one. Adults were not observed in flight. A few were taken in the following places: at the hatchery windows; on aquatic vegetation close above the surface of the water; and under the ends of some boards which overhung the water at the railway embankment, where the water pours out of the culvert, forming a little riffle. In this last mentioned place the nymphs were obtained. They were found crawling over the surfaces of the stones and boards among the brown and empty cases of Simulium pupae. One was bred July 31. Sweepings by day alongside the creek and trap lanterns by night failed to find this species.

From the foregoing bibliographic notes it will be apparent that this species is still practically undescribed.

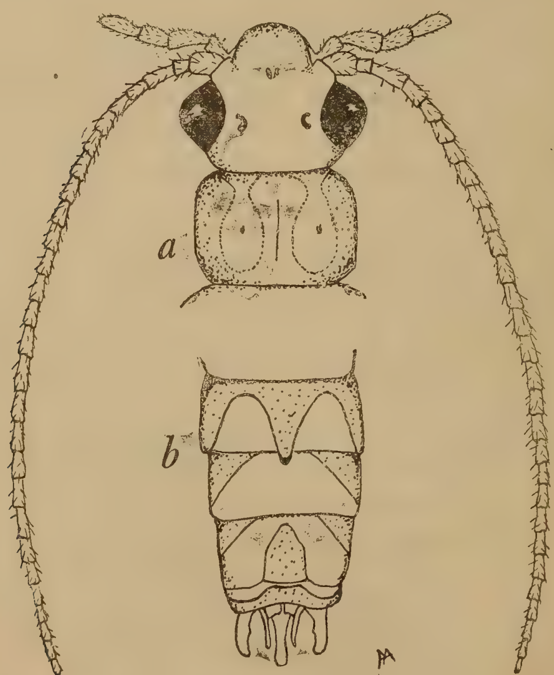


Fig. 4 Leuctra tenella, male: *a*, dorsal view of head and prothorax; *b*, end of male abdomen

**Imago.** Length, male 7.5 mm, female 9 mm to tip of wings; antennae, 5 mm. First and fourth segments of antennae of about equal length, the third longer, the second shorter, about 34 segments in all;

moniliform; not close set cylindric and tapering as in the more typical Perlidae. Median ocellus clearly double!

Body slender, with sides nearly parallel. The prothorax narrower than the head, regularly quadrangular, with straight sides and ends, and with angles all a little rounded; a faint median raised line and on either side of it a faint raised circle covering nearly half of the prothoracic dorsum.

Color brown, becoming yellowish on legs and sutures. Wings smoky hyaline with brown veins (*see* pl. 15, fig. 12).

On the dorsum of the abdomen in the male there is a conspicuous prominence on the seventh segment which rises to a hight equal to one fifth of the thickness of the abdomen (fig. 4*b*).

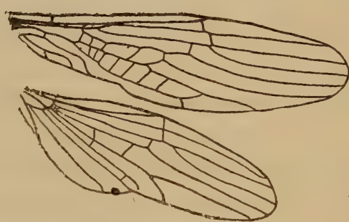

Fig. 5 Wings of Leuctra tenella

**Nymph.** Fully grown, measures 12 mm in length of head and body; abdomen alone 4.5 mm; antenna 4.5 mm; abdominal setae 4.5 mm. Width of head .9 mm.

Body with nearly parallel sides. Head as wide as the prothorax; mesothorax a little wider; abdomen a little narrower.

Color nearly uniform yellowish fulvous, pale below and on sutures, antennae and setae. Legs pale yellow. Eyes blackish; ocelli brownish, with a faint wash of brown between the posterior pair.

No tracheal gills.

Little Clear creek at Saranac Inn N. Y. June 21, 24, 26, 28, July 31 and Aug. 2, 1900. Not common.

The two stone flies discussed above fall in separate divisions of the family, which I regard as subfamilies, distinguishable by the following characteristics.

1 **Perlinae.** *Imago.* The median vein hardly fused with the radius at the base, but running close beside it, and bending away from it very gradually, not forming a distinct arculus.

*Nymph.* Flat body, flattened femora ciliate on the sharp and convex margins, and with tapering abdomen. Tracheal gills, when developed, consisting of tufts of filaments.

This subfamily includes the two tribes, Pteronarcini and Perlini of Banks.[1]

2 **Nemourinae.** *Imago.* The median vein fused with the radius at the base, then bending sharply away from it to meet the cross vein, with which it forms a distinct arculus.

*Nymph.* More cylindric body; femora not flattened or sharp edged; abdomen with nearly parallel sides. Tracheal gills when developed

1 Am. ent. soc. Trans. 1900. 24: 240.

consisting of single, isolated filaments.[1] This subfamily includes the two tribes, Capnini and Nemourini of Banks.

## Order EPHEMERIDA

### *May flies*

### Family EPHEMERIDAE

The May flies are all aquatic. A few of the larger species, which suddenly appear in countless numbers on the shores of our larger bodies of water and as suddenly disappear again, are very well known. But most May flies, being less concerted in their period of adult life, emerging a few at a time, resting under cover and returning to the water in the twilight to oviposit, are little observed.

The nymphs live in all sorts of fresh water, and are almost everywhere abundant. They are differentiated into highly specialized groups, each finely adapted to its own peculiar situation. There is great apparent similarity among the imagos; but the nymphs of the several principal groups are strikingly unlike. The struggle for existence has fallen mainly on the nymphs, and they have specialized for themselves, more or less independently of adult life. On this account, the beginner will find the study of the group greatly facilitated by collecting the nymphs along with the adults.

Nathan Banks has twice published keys for the determination of the genera of our North American May fly imagos, in the *Transactions of the American entomological society*, 19:332 and 26:246–47. Nearly all our species are described in Eaton's monograph.[2] The following table will serve for the separation of the nymphs of the genera occurring in our fauna. It will also serve to indicate what I believe to be the three principal natural divisions of the family, corroborated by important characters pertaining to both adult and nymphal life. It is based in part on the figures and tables of Pictet[3], Vaysseire[4], Eaton[2], and Schiller[5], but mainly on my own breedings of New York May flies. So few species have as yet been reared that this table will doubtless need considerable revision when more of the nymphs are known.

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1 Rarely developed. They are known from the European Nemoura cinerea Oliv., in which species there are six separate filaments at the front end of the prothorax beneath. An undetermined species of Nemoura, bred by me at Ithaca N. Y. possessed no gills whatever. I also bred at Ithaca an undetermined species of Taeniopteryx the nymph of which had attached to the posterior side of each coxa a single, tapering, three jointed, telescopic, gill filament.

In the Perlinae, the number of filaments in a tuft often increases with the age and size of the nymph.

2 Eaton. Revisional monograph o recent Ephemerinae. Linn. soc. Lond. Trans. (2) 3, 1888.

3 Pictet. Histoire naturelle des neuropteres: Ephemer. Paris 1843.

4 Vaysseire. Organization des larves des Ephemerines. Sci. nat. zool. Ann. (6) 11, 1881.

5 Schiller. Die Ephemeriden-larven Sachsens. Sitz. u. abh. der. naturwiss. ges. Isis in Dresden. 1890. p. 44–49, 2 pl.

**GENERA OF EPHEMERID NYMPHS IN EASTERN UNITED STATES**

*a* Body flat, widest across the rear of the head; eyes dorsal; legs depressed; adapted for clinging closely to flat surfaces. (Imagos have five freely movable segments to the hind tarsi)
(HEPTAGENINAE) Heptagenia, *sens. lat.*

*aa* Head not so wide as succeeding parts of the body; eyes lateral; (imago with but three or four freely movable segments to the hind tarsi, the basal segment at least coherent with the tibia)

*b* Body widest across the mesothorax; legs of the first and second pairs about equidistant at the base. (Imagos have the cubitus and the first anal vein nearly parallel toward the base) (BAETINAE)

*c* Gills completely concealed under the enormously enlarged, conspicuously four spined mesonotum .................................. Baetisca

*cc* Gills exposed; mesonotum normal

*d* Outer caudal setae fringed only on the inner sides; gills on abdominal segments 1–7; agile swimmers

*e* Gills simple

*f* Gills oval in outline, obtuse at the apex.................. Baetis

*ff* Gills lanceolate in outline, acute at the apex.. Centroptilum

*ee* Gills double, at least the anterior pairs

*f* Antennae hardly longer than the head; the thin lateral margin of the eighth abdominal segment produced posteriorly in a very large flat tooth; ocelli on the face................ Siphlurus

*ff* Antennae longer than half the body; the posterolateral angles of the eighth abdominal segment not forming a conspicuous tooth; ocelli generally on the top of the head

*g* Antennae shorter than the body; gill tracheae pinnately branched
Callibaetis

*gg* Antennae longer than the body; gill tracheae palmately branched
Cloeon

*dd* Outer setae fringed on both sides

*e* Gills on abdominal segments 1–7, double, similar

*f* Divisions of the gills narrowly linear.......... Leptophlebia

*ff* Divisions of the gills leaflike, each with a terminal filament
Blasturus

*ee* Gills absent from one or more of abdominal segments 1–7, one pair more or less elytroid, covering those behind it

*f* Gills present on the seventh abdominal segment, elytroid on the third or fourth segment; a pair of minute tubercles at the apical margin of each abdominal segment beside the median line
Ephemerella

*ff* Gills absent from the seventh abdominal segment, elytroid on the second segment; no dorsal abdominal tubercles...... Caenis

*bb* Body somewhat compressed, widest across the base of the abdomen; legs of the first pair much more closely approximated at the base than those of the second pair; all the legs appressed against the sides of the body and adapted for burrowing; mandibles usually produced anteriorly in a long, curved tusk. (Imagos have the cubitus and the first anal vein strongly divergent toward the base) EPHEMERINAE

*c* Head without frontal prominence; gill rudiment on the first abdominal segment simple.................................... Polymitarcys

*cc* Head with a frontal prominence; gill rudiment on the first abdominal segment bifurcated, shaped like a tuning fork

*d* Frontal prominence rounded; the flattened fore tibia with a broad, rounded lobe at its apex, close behind the apical burrowing hook ... Hexagenia

*dd* Frontal prominence bispinous; no conspicuous lobe at the apex of the fore tibia behind the apical burrowing hook... Ephemera

I describe below the nymphs of seven species of May flies, representing as many genera, bred at Saranac Inn. The only bred North American nymph of which I find description is the singular Baetisca obesa Say, which is figured by Walsh, Vaysseire and Eaton. A number of undetermined American nymphs, mostly from the Cambridge museum of comparative zoology, are figured and described in Eaton's monograph. One of these I have been able to identify as Ephemerella excrucians, described below.

## Heptagenia pulchella Walsh

Plate 15, figure 15

1862 Palingenia pulchella Walsh, Acad. nat. sci. Phil. Proc. p. 375 (original description)

1863 Palingenia pulchella Hagen, Ent. soc. Phil. Proc. 2:177 (note)

1863 Palingenia pulchella Walsh, Ent. soc. Phil. Proc. 2:203 (note)

1863 Heptagenia pulchella Walsh, Ent. soc. Phil. Proc. 2:204 (merely refers it to Heptagenia)

1871 Heptagenia pulchella Eaton, Ent. soc. Lond. Trans. p. 141 (description in Latin from the original by Walsh)

1885 Heptagenia pulchella Eaton, Linn. soc. Lond. Trans. (2) 3:299 (a very full description)

1892 Heptagenia pulchella Banks, Am. ent. soc. Trans. 19:347 (listed)

Imagos of this species were common in the hatchery windows throughout our session, and during the month of June were most abundant there. A few, mostly males, were taken regularly in the trap lanterns when the weather was favorable. A few others were seen, flying in the twilight. The species was little in evidence, common as it was.

The nymphs were abundant in Little Clear creek, specially in the more rapid places, clinging closely to flat surfaces of boards, sticks, stones, etc. To collect them one needed but to lift these obstructions from the stream and pick the nymphs from them with forceps. Within a few days after our arrival we had reared some of the nymphs, and others were reared repeatedly after that. Oviposition was not observed. I dissected a female subimago, and counted the eggs in her ovaries in part, and, on the basis of this count, estimated the whole number at about 1340. Imagos and subimagos thrown on the surface of the fish ponds

were snapped up eagerly by the trout. The membrane of the wings of the imago is in this species finely iridescent.

**Nymph.** Pl. 15, fig. 16 Length of body 10 mm; setae, male 12, female 15 additional; abdomen, male 6.25, female 7.

Body flat; lateral margins of the head and prothorax thin, sharp edged, flaring, that of the head projecting distinctly beneath the eyes, antennae reaching the tips of the extended fore femora; all femora flattened, sharp edged, edges very convex and fringed with hairs.

Color yellowish or greenish brown, mottled, paler below, and dorsally marked with paler spots as follows: an inverted, mushroom-shaped spot before the middle ocellus, a triangular patch between each reniform, lateral ocellus and the eye, a transverse band at the rear of the head; an oblique band each side of the prothorax, a large lateral spot each side of each of the intermediate abdominal segments with a black mark at its hind margin. The femora and tibiae show very indistinct transverse banding of color.

Abdomen with sharply toothed posterolateral angles on its hindmost segments, the tooth largest on the eighth segment, where it surpasses the middle of the ninth segment, smaller on the seventh and ninth, and a mere sharp angle on the sixth segment. Setae sparsely fringed with hairs for a third of their length.

Gills present on segments 1–7, similar on 1–6, though becoming smaller posteriorly. Anterior gills double, the anterior leaf thickened, trapezoidal with the angles all obtuse, a sparse fringe of slender hairs around the distal half of its border, a strong oblique, longitudinal ridge on its anterior face near its ventral edge; posterior leaf thin and delicate, covered by the anterior, smaller than the anterior, cordate triangular in general outline, cut into a peripheral fringe of long respiratory filaments which are once or twice forked or simple, the fringe being as long as the body of the leaf. Gill of the seventh segment simple (corresponding to the anterior leaf only), lanceolate, fringed along its entire margin, its apex surpassing the lateral tooth of the eighth abdominal segment.

This species is known from Rock Island Ill., Maryland, New York and Quebec.

There is in the Museum of comparative zoology a specimen of another species labeled "Adirondacks, New York, Aug. 1872" in Dr Hagen's handwriting, which agrees entirely with other specimens in the same museum bearing the name Heptagenia vicaria Walker.

## Baetis pygmea Hagen

Plate 15, figures 13, 14

1861 Cloe pygmea Hagen, Synopsis Neur. N. Am. p. 54 (original description)

1863 Cloe pygmaea Hagen, Ent. soc. Phil. Proc. 2:178–79 (notes, "It is the smallest ephemerous species known.")

1871 Baetis pygmaeus Eaton, Ent. soc. Lond. Trans. p. 122 (original description, repeated in Latin)

1885 Baetis pygmaeus Eaton, Linn. soc. Lond. Trans. (2) 3:170 (a new description of the fragments remaining of the type)
1892 Baetis pygmaea Banks, Am. ent. soc. Trans. 19:348 (listed)

All the above are bare descriptions of the single female specimen in the Hagen collection from the St Lawrence river.

I studied this fragmentary type specimen in Cambridge Aug. 25 and 28. There remains of it a bit of the thorax, bearing the greater part of one fore wing. The venation of this wing furnished the only points for critical comparison with my specimens. The descriptions and the type specimens agree fairly well with the smallest of my specimens. I could not see the brownish color of the veins described by Eaton either in my specimens or in the type. Also the veins in the pterostigmatic space vary in number in my specimens from 5 to 12, and from being simple and straight to being forked and anastomosing.

This species, like the preceding, was common in the hatchery windows, was taken often sparingly in the trap lanterns, and was seldom seen at large. Imagos occurred more sparingly, however, through the earlier part of the season, but they became very abundant in August. From the window in the hatchery nearest the mouth of the inflow pipe carrying surface water, hundreds of imagos and subimagos could be picked at a time. These were preyed on in great numbers by spiders which lurked in the crevices of the window casings. Not a few flew against the window panes when these were wet with condensations in the mornings, and, striking their wings, adhered, and were unable to free themselves. When the moisture evaporated, these were dried down on the glass. Among these I noticed a number of females which had discharged the contents of their ovaries on the pane in masses of about 200 eggs each.

Nymphs of this species were found most abundantly among the cases of Simulium pupae in swiftly flowing water; a few could be taken at any time from the hatchery troughs.

This is the daintiest, and one of the prettiest of our May flies. It is still so insufficiently known that I will append hereto complete descriptions of the stages known to me.

**Male imago.** Length 3–5 mm; setae 7 mm additional. Colors black and white varied with reddish brown and yellowish red. Head yellowish, with the ocelli and the inferior part of the eyes black, turbinate superior part of the eyes yellowish red on the sides, reddish brown on the superior, corneal surface.

Thorax black, paler on the lateral sutures. Legs, antennae and setae pale yellowish white; fore legs darker on the sutures. Wing very transparent with a faint wash of yellow on the extreme base. Hind wing bivenulate, sometimes with a short third vein.

Abdomen black and white; segments 2–5 pure white (in old males) with black spiracles; segment 6 yellowish; segments 7–10 black, paler below.

**Male subimago** (undescribed). Differs only in having the setae about 5 mm long (as in the female); and in lacking strongly contrasting black and white colors on the abdomen, all the colors being duller, the wings merely translucent, with a fine fringe of hairs.

**Female imago.** Length 3–5 mm, setae 5 mm. Color reddish brown, darker on the thorax and paler beneath the body; discoloring badly when pinned. Head and thorax brownish with ocelli paler and eyes black. Thoracic dorsum brown, darker on the ridges, with a pair of oblique pale stripes extending from the hind angles of the prothorax to the wings, and a pair of narrow, submedian, longitudinal stripes on the mesothorax.

Abdomen reddish brown, apical segments paler.

**Female subimago.** Differs in obscurer coloration; on the top of the mesothorax there is a single wide middorsal longitudinal stripe.

Known only from the St Lawrence river and Saranac Inn. Specimens are deposited at Cambridge in the Museum of comparative zoology and in the New York state museum.

**Nymph.** Measures 4–5 mm; setae 2.3–2.5 mm additional; antennae 2.2 mm.

Body slender, graceful, smooth, clean; brownish above, yellowish beneath and on the sutures; a narrow middorsal yellowish line, dilated on the middle of the mesothorax, and expanded again into a quadrate spot at the front of the prothorax; paired yellowish markings beside this line, and numerous small yellowish spots nearer the sides; legs and antennae yellowish. Setae with a brownish shade near the bare tip; all fringes short; the two outer setae fringed only on the inner side.

Gills present on abdominal segments 1–7. small, separate, widely extended and fully exposed; each leaf obovate, a little oblique, with a chitinous thickened inferior border, this border, short on the foremost gill leaf, reaches the apex on the sixth one, and comprises the greater part of the narrow, reduced seventh one.

The face is vertical, with the ocelli in front, somewhat as in Siphlurus.

The nymph is an exceedingly agile, little fellow, darting hither and thither with astonishing speed when one tries to pick it up.

A few specimens of a larger, undetermined species of Baetis were taken at the hatchery windows.

## Siphlurus alternatus Say

Plate 11, figure 7

1824 Baetis alternatus Say, Godman's western quart. reporter, 2:304
1859 Baetis alternatus Leconte (ed.), Complete writings T. Say, 1:204
1861 Baetis alternatus Hagen, Synopsis Neur. N. Am. p. 49
1862 Baetis alternatus Walsh, Acad. nat. sci. Phil. Proc. p. 369
1863 Baetis alternatus Hagen, Ent. soc. Phil. Proc. 2:169

1863 Baetis alternatus Walsh, Ent. soc. Phil. Proc. 2:189
1853 Baetis annulata Walker, List Neur. ins. Brit. mus. 3:567
1861 Baetis annulata Hagen, Synopsis Neur. N. Am. p. 48
1876 Baetis femorata Provancher, Nat. Canadienne. 8:267
1877 Baetis femorata Provancher, Faun. ent. du Canada. 2:83
1871 Siphlurus annulatus Eaton, Ent. soc. Lond. Trans. p. 127 (description in Latin: figures of forceps of male, and ventral abdominal markings in pl. 6, fig. 4 and 4a)
1871 Siphlurus alternatus Eaton, Ent. soc. Lond. Trans. p. 129
1877 Siphlurus alternatus Provancher, Faun. ent. du Canada. 2:83
1885 Siphlurus alternatus Eaton, Linn. soc. Lond. Trans. (2) 3:219
1892 Siphlurus alternatus Banks, Am. ent. soc. Trans. 19:346 (listed)

This handsome brown species was not observed at large, was not taken in our trap lanterns, and was only obtained by rearing nymphs. These were not uncommon in shallow water about the outlet of Little Clear pond among the debris of fallen brushwood. Doubtless the imagos might have been found at large, had careful search been made of the shores about these same places.

The nymph is a graceful creature, and exceedingly agile. The beautiful fringes on the abdominal setae constitute a powerful tail fin, one stroke of which sends the nymph through the water with a speed the eye can hardly follow. It is exceedingly difficult to pick up one of the nymphs, when confined in a little dish of water, with a forceps, so quickly will they dart away. In a water net of some size they are easily taken, however, apparently not finding themselves ensnared till lifted from the water. A good many specimens were taken in shallow water behind a large hummock overgrown with cattails (Typha) to the north of the outlet of Little Clear pond. These transformed July 21, 22 and 23, and remained in the subimago stage for more than 48 hours in every case, undergoing the final molt during the second day after emergence from the larval skin.

This species is widely distributed throughout the eastern United States.

**Nymph.** Pl. 11, fig. 5, 6 Length of body 15 mm; setae 6.5 mm additional; abdomen 9.5 mm; antennae 1 mm.

Body arched, tapering, very graceful and exceedingly well adapted for swimming. Abdomen somewhat depressed and upcurved at the tip. Face vertically elongated, with an aspect singularly like that of the face of the common grasshopper.

Head and prothorax short, each about twice as wide as long; mesothorax large and prominent; abdomen a little wider in the middle, tapering slightly to the end, serrated on each side by the prolongation of the posterolateral angles of segments 1–9 in sharp, single, backwardly directed teeth, which become largest on the sides of the 8th segment, and sharpest and thinnest on the sides of the ninth: 10th segment cylindric, two thirds as wide as the ninth.

Color yellowish or greenish brown, mottled with blackish brown on the dorsal side in a pattern of short streaks. Legs yellowish: femora with a band of brown just beyond the middle; other brownish marks beside or on all the leg sutures; tibia shorter than the tarsus without its claw.

Setae yellow, with a whitish fringe of hairs of silky aspect; a transverse band of brown across them just beyond the middle, and a brownish shade near the tip.

Gills present and double on segments 1–7; the posterior leaf with a chitinous ridge on its ventral (external) margin, not reaching the apex, relatively shortest on the first gill; the posterior leaf trilobed on segment 1, bilobed on segments 2–6, and simple on segment 7; the smaller, thinner and more delicate anterior leaf bilobed on segments 1 and 2, simple on segments 3–7, becoming very small on the seventh segment.

In contrast with the gills of Heptagenia, in which the anterior leaf of the gill is thickened and protects the delicate posterior one, we have in Siphlurus the anterior leaf thin and delicate, the posterior one thickened. The latter, having muscles attached to it internally, thus becomes a swimming organ, capable of a smart backward stroke. Each acts in concert with its fellows and with the tail fin, producing a racing speed for a succession of short dashes through the water. The respiratory gill leaf, being placed at the front, is out of the way of the stroke.

Two specimens of Callibaetis ferruginea were taken at the hatchery windows during the month of August.

## **Ephemerella excurcians** Walsh

1862 Ephemerella excrucians Walsh, Acad. nat. sci. Phil. Proc. p. 377 (original description)

1863 Ephemerella excrucians Hagen, Ent. soc. Phil. Proc. 2:178 (note)

1885 Ephemerella excrucians Eaton, Linn. soc. Lond. Trans. 3:130 (a full description)

1892 Ephemerella excrucians Banks, Am. ent. soc. Trans. 19:347 (listed)

1871 Ephemerella invaria, in part, Eaton, Ent. soc. Lond. Trans. p. 100

Very few imagos of this interesting species were obtained, notwithstanding the nymphs were common in Little Clear creek and even in the hatchery troughs during the month of July. A single pair was bred July 10, transforming to imagos the following day. Specimens were taken at the trap lantern and from the hatchery windows. The species is known from New York, Illinois and Michigan.

The nymph is no. 5 of Eaton's monograph.[1] This being the type species of the genus Ephemerella, a genus the nymphs of which show considerable differences, it is the more desirable that the immature stages should be made known.

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[1] Linn. soc. Lond. Trans. 1885. 3:133–34, pl. 40, fig. 18–20, and pl. 64, fig. 3–7. Unknown genus "allied to Ephemerella."

**Nymph.** Length 8 mm; setae 4 mm additional; abdomen 4.5 mm; antennae 1.5 mm.

Head twice as wide as long; thorax convex; legs short; tibia about equal in length to the tarsus without its claw; abdomen depressed, widened on the fourth to ninth segments, with thin lateral margins, produced at the hind angles into thin, flat teeth, which appear in outline like the teeth of a circular saw; third segment with a minute tooth, first and second segments with none at all, 10th segment with a low, longitudinal, lateral carina; setae fringed in the middle, nearly naked at both ends.

Color dirty yellowish, darker above, paler beneath.

Gills double, well developed on the fourth to the sixth segments, rudimentary on the first and seventh, and absent from the second and third; the opercular anterior leaf on the fourth segment covers all the gills posterior to it; on the fifth and sixth segments the anterior leaf is similar in form but smaller and much thinner; the delicate posterior leaf on the fourth, fifth and sixth segments is two parted; on the first segment is a simple cylindric rudiment, jointed on a low pedicel; on the seventh segment the rudimentary gill is leaflike, single, six lobed.

July 19 quite a number of nymphs were obtained, both from Little Clear creek beside the hatchery and from the hatchery troughs.

## Caenis diminuta Walker

1853 Caenis diminuta Walker, List neur. ins. Brit. mus. 3 : 584

1861 Caenis diminuta Hagen, Synopsis Neur. N. Am. p. 55

1861 Caenis amica Hagen, Synopsis Neur. N. Am. p. 55

1871 Caenis diminuta Eaton, Ent. soc. Lond. Trans. p. 95 (description in Latin)

1885 Caenis diminuta Eaton, Linn. soc. Lond. Trans. (2) 3 : 147 (a full description)

1892 Caenis diminuta Banks, Am. ent. soc. Trans. 19 : 348 (listed)

This dumpy, little, nocturnal species was taken abundantly in a trap lantern hung on the side of the boathouse at the outlet of Little Clear pond. 15 to 50 specimens were taken at a single lantern each evening from the 14th to the 18th of July. This appeared to be the season of greatest abundance for the species. It is quite variable in size and in coloration: the best colored of my specimens agree well with Eaton's detailed description; but the size is often much larger, reaching 5–6 mm in length. This may be due to the taking of published measurements from dried specimens, which are always shriveled considerably. The species is generally distributed over the eastern United States.

The nymphs are common among the trash on the bottom in all quiet waters. Their inconspicuous coloration and trashy covering protect

them well. They cling closely to twigs, bark, etc., and will allow themselves to be lifted from the water without stirring.

**Nymph.** Length 5.5 mm; setae 3.4 mm additional; abdomen 2.5 mm; antenna 2.3 mm.

Body stout, with thick thorax, and short and rapidly tapering abdomen.

Color pale brownish, darker above, obscured by adherent silt, by diatoms, vorticellae, hydras, and other adherent organisms.

Abdomen with large and sharp, flat teeth, made by the projecting posterolateral angles of the third to the ninth segments, largest on segment 7, smallest on segment 3.

Gills present on segments 1–6; on segment 1 minute rudiments; on segment 2 thick, elytroid, covering the functional gills, squarish, the distal and external angles rounded, the basal-internal angle square; there is on the anterior face a piliferous carina, regularly arcuate, near the external margin, extending from the outer basal to the inner distal angle. The gills on segments 3–6 diminish in size posteriorly; they have the shape of the hind wing of a pierid butterfly, and bear a long dense peripheral fringe of respiratory filaments. These filaments are unilaterally several times branched on the anterior side, and are so closely crowded that they overlap in regular series around the margin of the gill leaf. They are longest at the distal end, where they exceed the length of the gill leaf itself.

Setae slender, thinly fringed along both margins, the middle one apparently a little shorter in the males, a little longer in the females than the other two.

## **Hexagenia variabilis** Eaton

Plate 16

1843–45 Palingenia limbata Pictet, Hist. nat. Neur. v. 2 (Ephem.) p. 146, pl. 12 (the original description: this was Serville's name for another species)

1853 Palingenia limbata Walker, List neur. ins. Brit. mus. 3:548

1861 Palingenia bilineata Hagen, Synopsis Neur. N. Am. p. 41 (a full description)

1862 Palingenia limbata Walsh, Acad. nat. sci. Phil. Proc. p. 373

1863 Palingenia limbata Hagen, Ent. soc. Phil. Proc. 2:176

1863 Palingenia limbata Walsh, Ent. soc. Phil. Proc. 2:197–99 (makes the species the type of his new genus Hexagenia)

1868 Hexagenia limbata Eaton, Ent. mo. mag. 5:85

1871 Hexagenia limbata Eaton, Ent. soc. Lond. Trans. p. 65, pl. 1, fig. 7, and pl. 4, fig. 3 and 3a (description in Latin)

1885 Hexagenia variabilis Eaton, Linn. soc. Lond. Trans. (2) 3:55, pl. 7, fig. 11c

1890 Hexagenia variabilis Hagen, Stett. ent. zeit. 51:11–13 (distinguishes this species from bilineata Say by the form of the forceps of the male)

1892 Hexagenia limbata Banks, Am. ent. soc. Trans. 19:345 (listed)

1888 Hexagenia sp.? (probably variabilis and bilineata) Forbes, State lab. nat. hist. Bul. 3. 2:484–85 (estimate of the value of Hexagenia larvae as food for fishes, based on the examination of the stomach contents of 1221 fishes, representing 87 species, 63 genera, and 25 families: Hexagenia larvae constitute nearly one tenth of all the food taken). Summary in Insect life. 1888. 1:158–61

This species was much less numerous than the other six whose life histories are discussed here. It was found only along Little Clear creek. An occasional subimago was seen in early morning leaving the water and flying weakly to some neighboring tree trunk to rest. A single specimen was taken on the outside of a trap lantern in the morning twilight. A few were picked from the sides of the hatchery building, where they were conspicuous on account of their size.

The nymphs were easily obtained from the bottom of the creek with a sieve net. They were obtainable throughout the season, this species not having a limited period of emergence, as H. bilineata seems to have. Nymphs taken incidentally while collecting, were reared at various times from June 26 to Aug. 1. They were associated in the creek bed with Ephemera varia, described below, but were very much less numerous. In our breeding cages the subimago emerged one night and transformed to the imago the night following.

**Nymph.** Pl. 16, fig. 2, 3. Length of body 27 mm; setae 12 mm more; abdomen of male 18, of female 21 mm; antenna 4.5 mm.

Color yellow, with some paler longitudinal markings on the thorax; a series of mushroom-shaped marks on abdominal segments 6–9.

Head compressed; a shelf like prominence above the base of each antenna, straight on its front border, round on its exterior side; the frontal prominence semi-elliptic; mandibular tusks long, stout, upcurved, with a line of hairs on their supero-external margin.

Antennae at base, and the sharp edges of the legs, and the lateral margins of the prothorax, densely clothed with long yellowish hairs. The antennae are bare at the tips and do not surpass the extended fore tarsi.

Legs (pl. 16, fig. 3) short, stout, twisted, flattened, closely applied to the sides of the body, and well adapted for burrowing; femora and tibiae scapulate; the tibia produced at its apex into a terminal burrowing hook and scraper, the edges bearing a stiff line of hairs; the hind foot chelate, the distal angle of the tibia forming with the opposed tarsus a pincer.

Gills on segments 1–7; gill of the first segment small and shaped like a tuning fork; of the six following segments large, of a rich purplish color, two leaved, the leaves similar, lanceolate, and densely fringed with minute linear respiratory filaments, which are as long as the greatest width of the gill leaf. On the flat side of each gill leaf is a yellow, longitudinal median line closely bordered on either side by a line of black. All the gills are directed over the back, where they are gently waved back and forth in intermittent, graceful motion.

One of the largest of our May flies; generally distributed over the United States east of the Rocky mountains.

## **Ephemera varia** Eaton

Plate 11, figures 3, 4

1861 Ephemera decora Hagen, Synopsis Neur. N. Am. p. 38 (decora was Walker's name for another species)
1875 Ephemera decora Hagen, Rep't U. S. geol. sur. terr. for 1873; p. 578
1885 Ephemera varia Eaton, Linn. soc. Lond. Trans. (2) 3:69–70, pl. 63, fig. 12h
1892 Ephemera decora Banks, Am. ent. soc. Trans. 19:345 (listed)

This dainty New England species was common about Little Clear creek, associated with the preceding species, with which it agrees quite closely in habits. Imagos, while not sought outside our cages, were often seen sitting lightly on the bushes near the banks of the creek. The nymphs were abundant in the bed of the creek till the first of August.

**Nymph.** Pl 11, fig. 1, 2 Length of body 18 mm; setae 8 mm additional; abdomen 11 mm; antennae 4.5 mm.

Color yellowish; abdomen with a pair of submedian, longitudinal, brown streaks, laid on yellow ones, which they divide.

Antennae sparsely hairy, much surpassing the tips of the tarsi. Mandibular tusks, approximate, slender, bare, gently up curved and divergent at the tips; femora and tibiae moderately dilated and bearing on their flattened edges copious fringes of hairs.

Gills as in Hexagenia, but slenderer, and less deeply tinged with purple color.

## Order ODONATA

### *Dragon flies*

The dragon flies are all aquatic. They frequent fresh water in all sorts of situations, and are probably the most important predatory aquatic insects. They are strictly carnivorous in all stages. The adults feed on a great variety of insects, and the larger dragon flies habitually eat the smaller ones. The nymphs are very voracious, and in many species cannibalistic, the larger nymphs eating the smaller ones; but they eat chiefly other aquatic insects, worms, crustaceans, fish fry, and tadpoles.

Fig. 6 Face of nymph of Sympetrum illotum Hagen, showing the enormous mask shaped labium

The nymphs may be conveniently grouped according to habits as follows.

*a* Burrowing nymphs, with depressed, wedged-shaped heads, abbreviated and flattened antennae, approximated fore legs, and external burrowing hooks at the ends of the fore and middle tibiae. These burrow along on the bottom of the pond or stream, just beneath the layer of silt, with the tip of the abdomen turned upward and reaching the water for respiration (Gomphinae)

*b* Squatting nymphs, with the face vertical and the eyes capping the prominent anterolateral angles. These settle themselves on the trashy pond bottom, some of them covering themselves over completely with sand or silt, and thus await in ambuscade the approach of their prey (Cordulegasterinae, Macromiinae, and some Libellulinae)

*c* Climbing and clinging nymphs, with cleaner, slenderer, more active bodies, generally showing a definite color pattern, with the head neither cuneate nor vertical in front (Agrionidae Aeschninae, and some Libellulinae)

All nymphs, when ready for adult life, crawl up some support above the edge of the water, fix their claws firmly and transform; the old nymph skin is left attached when the imago flies away. Since this skin preserves well the form of the nymph, and can be pinned for the cabinet, an easy way to gather life history material for dragon flies is to pick them up when newly transformed and before the imagos are ready to fly, place in a coarse paper bag each imago with its cast nymph skin, writing locality, date, etc., on the bag and closing its top, leave a day or more till the imago assumes its mature coloration, and then preserve as specimens, being always careful so to label imago and nymph skin that future mixing of specimens will be impossible.

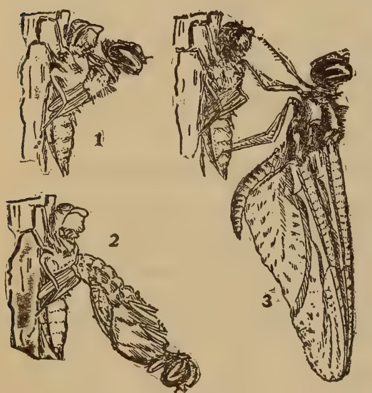

Fig. 7 The transformation of Plathemis lydia Dru. 1, 2, 3, three stages in the emergence of the imago from the old nymph skin

The two suborders, of which but one is treated in this paper, may be readily recognized by the following characters.

*a* Fore and hind wings similar, held vertically in repose: *nymphs* with three large leaflike respiratory plates at the apex of the slender abdomen, and with the body tapering posteriorly from the head. Suborder ZYGOPTERA: damsel flies

*aa* Fore and hind wings dissimilar, the latter broader at the base: *nymphs* without external respiratory plates, but with a respiratory chamber included within the wide abdomen; body less slender, and not widest across the head. Suborder ANISOPTERA; dragon flies proper

## Suborder ANISOPTERA

The dragon fly fauna of New York state is somewhat more extensive than that of the few other states in which careful collecting has been done. Dr P. P. Calvert has summarized the local lists of the dragon flies of the state in the Journal of the New York entomological society,[1] giving

[1] 1895, 3:39-48 and 1897, 5:91-96.

all the recorded localities of occurrence within the state. The list includes 102 nominal species. In the suborder Anisoptera belong 67 of these, to which I am able to add 15 species and varieties not hitherto recorded. These are: Ophiogomphus aspersus Morse, O. johannus Ndm. (O. carolus Ndm. has been previously listed as O. mainensis Pack.) Gomphus abbreviatus Hag., Gomphus scudderi Sel., G. quadricolor Walsh, G. furcifer Hag., G. sordidus Hag., G. descriptus borealis n. var., Cordulegaster maculatus Sel., Tetragoneuria spinosa Hag., Cordulia shurtleffi Scudd., Ladona julia Uhl. and Leucorhinia glacialis Hag. I am able also to describe the nymphs of all the genera herein characterized, except two: Gomphaeschna, and Micrathyria, and in many of them, to describe the nymphs of a number of species.

Immature stages in this order are still very little known. Of the 80 species herein discussed, I find that the nymphs of 20 have been more or less completely described and referred to their proper species; 18 of these have been described by Hagen and Cabot, and most of them, well figured; the nymph of one of our species which occurs also in Europe, Libellula quadrimaculata Linn., has long been known in the old world; and recently E. B. Williamson has been able to get for description the nymph of Tachopteryx thoreyi Selys, our sole representative of the Petalurinae and thus to fill one of the most important gaps in our knowledge of the immature stages. Most of these are briefly redescribed below, and 42 new descriptions are added. Thus the early stages are more or less known for 62 of our 80 species.

With three exceptions I have given herein no descriptions of imagos: The descriptive catalogues of Calvert, Kellicott, and Williamson, and other available special papers contain descriptions which it is hardly profitable here to duplicate. In absence of these I trust the keys and tables herein given may be sufficient for the determination of the species.

In the bibliographies given below, completeness has not been aimed at: the student who desires complete bibliography should consult the three following bibliographic catalogues.

**Hagen, H. A.** Synopsis of the Odonata of America. Bost. soc. nat. hist. Proc. 1875. 18:20-96.

**Banks, Nathan.** Synopsis, catalogue and bibliography of the neuropteroid insects of temperate North America. Am. ent. soc. Trans. 1892. 19:327-73

**Kirby, W. F.** Synonymic catalogue of Neuroptera Odonata, or dragon flies. Lond. 1890.

Of these three papers the first named is most complete for the period it covers, and it is the only one containing any reference to the literature of the immature stages.

The four descriptive papers most continuously referred to in the bibliographies of imagos are:

**Hagen, H. A.** Synopsis of the Neuroptera of North America. Smithsonian inst. Misc. coll. 1861.

**Calvert, P. P.** Catalogue of the Odonata of Philadelphia and vicinity. Am ent. soc. Trans. 1893. 20:152–272, 2pl.

**Kellicott.** Odonata of Ohio (a posthumous paper, completed and edited by James S. Hine). O. state acad. sci. Special papers, no. 2. 1889.

**Williamson, E. B.** Dragon flies of Indiana. Dep't geol. and natural resources of Indiana. 24th an. rep't 1900. p. 233–333, 7 pl.

The first of these papers is out of print; the others may be obtained through the organizations under whose auspices they were published.

The bibliographies given below, being solely designed to aid the user of this paper, are intended to cover the following points.

1 The original description of the species

2 The principal descriptions which have introduced synonyms

3 All available descriptions and figures in American periodicals

4 The records of the occurrence of the species in this state; at least Calvert's summary of such records. (In most cases I have not thought it desirable to go back of this: Calvert's paper is cited on p. 430).

5 All available descriptions and figures of the nymphs of our species.

It will be convenient to treat here as families the two groups that are so recognized in the descriptive works to which our bibliographic references refer. These may be separated by the following keys. The technical terms used in the keys are explained in figures 8 to 10.

## KEY TO FAMILIES

### *Imagos*

*a* Triangle (*see* fig. 9) about equally distant from arculus in fore and hind wing; stigma with a brace vein at it sinner end (except in Cordulegaster) .......... Aeschnidae p. 434

*aa* Triangle in the hind wing much nearer the arculus than in the fore wing; stigma without brace vein .......... Libellulidae p. 478

### *Nymphs*

*a* Labium (*see* fig. 8) flat or nearly so, without raptorial setae (except in Cordulegaster, which has the labium spoon shaped, and the median lobe cleft at the summit of a prominent median angle into two divergent teeth) .......... Aeschnidae

*aa* Labium mask shaped or spoon shaped, when closed covering the face up to the bases of the antennae, armed with raptorial setae.... Libellulidae

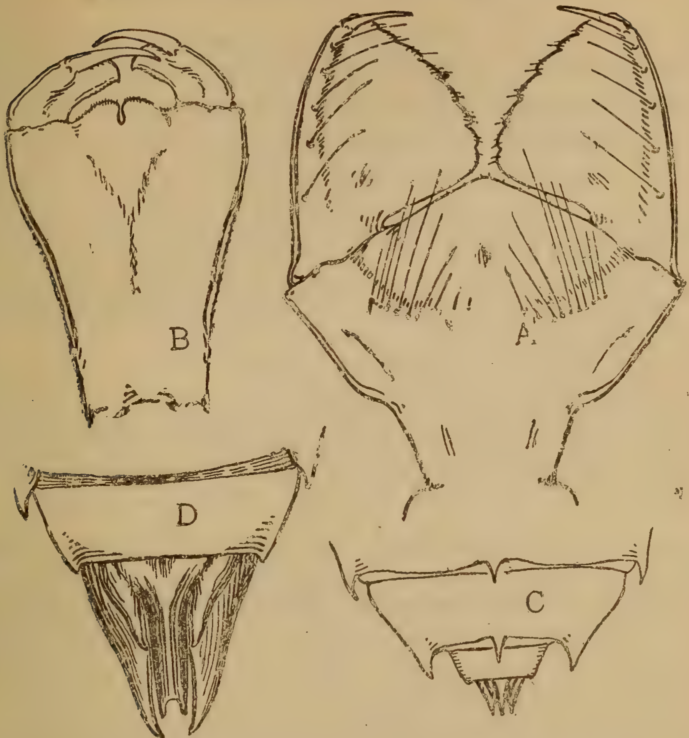


Fig. 8 Group recognition characters for dragon fly nymphs. B and D, labium and end of abdomen of Anax junius Dru. (Aeschninae) A and C, labium and end of abdomen of Perithemis domitia Dru. (Libellulinae)

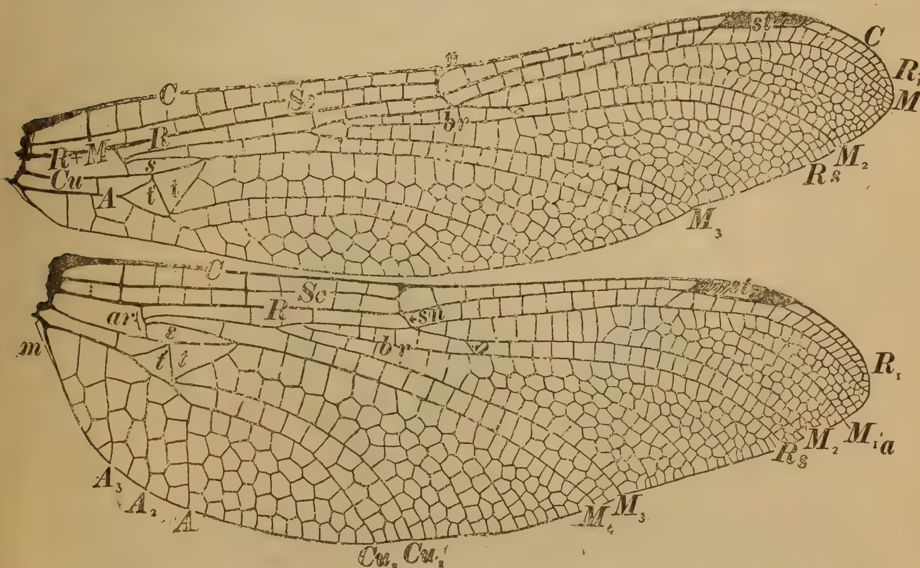


Fig. 9 The wings of Gomphus descriptus Banks. *C* costa; *Sc* subcosta; *R* radius; *Rs* radial sector; *M* media; *Cu* cubitus; *A* anal vein; *n* nodus; *br* bridge; *o* oblique vein; *sn* subnodus; *st* stigma: *ar* arculus; *t* triangle; *t'* subtriangle; *s* supratriangle: *m* membranule. Branches of media, cubitus and anal vein membered at the wing margin. The dotted line in the base of the subcostal space indicates the position of the basal subcostal cross vein when developed.

## Family AESCHNIDAE

This family contains four subfamilies that are so different in character and habits they may be best discussed separately. The following keys will serve for their separation.

### KEY TO SUBFAMILIES

*Imagos*

*a* Stigma braced at its inner end against an inclined cross vein in the space below it (see fig. 9)

*b* Cubital vein in the fore wing extending directly to the hind angle of the triangle, not appearing forked; subtriangle consisting of one cell, or indistinctly developed

*c* Eyes widely separated on the top of the head............ Gomphinae

*cc* Eyes approximated on the top of the head ...... Aeschninae p. 462

*bb* Cubital vein in the fore wing apparently forked at the base of the second cubito-anal cross vein; subtriangle of three cells. Petalurinae p. 472

*aa* Stigma without a brace vein.............. Cordulegasterinae p. 473

*Nymphs*

*a* Labium flat (or with the edges of the lateral lobes slightly upturned in Tachopteryx), and without raptorial setae

*b* Labium with its median lobe entire; antennae four jointed, the fourth joint rudimentary; fore tarsi two jointed: burrowing nymphs. Gomphinae

*bb* Labium with a short median cleft (fig. 8B); antennae seven jointed, setaceous; tarsi three jointed: climbing nymphs, with eyes at sides of head Aeschninae

*bbb* Labium with a shallow median cleft (fig. 15); antennae seven jointed, short; squatting nymphs, with face vertical, and eyes on anterolateral angles; depressed, hairy; tarsi three jointed .......... Petalurinae

*aa* Labium spoon shaped, with raptorial setae, differs from libellulid nymphs in having the prominent median lobe of the labium cleft into two variously formed teeth at apex (fig. 16)......... Cordulegasterinae

## Subfamily GOMPHINAE

Mostly large species, with clear wings, bodies striped with black and green or yellow, of strong but not well sustained flight, inhabiting mostly

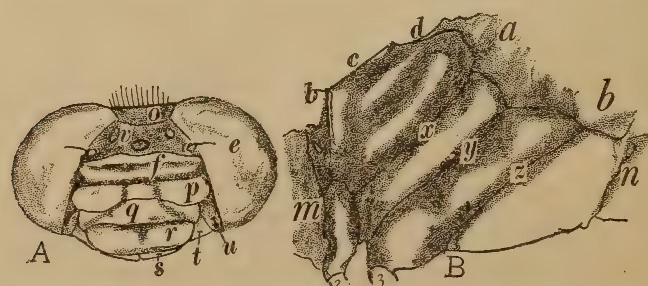


Fig. 10 Diagram illustrating the parts of the head and thorax chiefly used in the tables (Lanthus albistylus Selys). *A* head seen from front; *e* eye; *f* frons; *p* postclypeus; *q* anteclypeus; *r* labrum: *s* edge of labium; *t* side of mandible; *u* gena: *v* vertex, bearing the three ocelli and the antennae; *o* occiput. *B* Thorax from the side; *m* prothorax; *n* abdomen; *a* and *b* consolidated meso- and metathorax; *b* collar; *c* carina; *d* crest; *x*, *y*, *z* first (humeral), second and third latural sutures and stripes; 2 and 3, bases of middle and hind legs respectively

flowing or clear water; abundantly represented throughout New York state. The nymphs are burrowers in the beds of streams and ponds. The females oviposit unattended by the males, and liberate their eggs in the water during flight by descending repeatedly and striking the surface of the water with the tip of the abdomen. The eggs have a scanty envelop of gelatin; they tend apart in falling, to lie scattered on the bottom, where they are at once hidden by the silt which adheres to the gelatin. The following key will serve for the separation of the genera likely to be found within our limits.

### KEY TO GENERA

*Imagos*

*a* Basal subcostal cross vein (*see* fig. 9) present; a linear or spatulate, median, sternal process on the first abdominal segment; legs very short, the hind femora hardly reaching the apex of the first abdominal segment ........................................ Progomphus

*aa* No basal subcostal cross vein; no median sternal process on the first abdominal segment; legs longer, the hind femora reaching or surpassing the middle of the second abdominal segment

*b* Hind wings with a distinct anal loop (*see* fig. 18 a) consisting of several cells

*c* Anal loop normally consisting of three cells; first and fifth antenodal cross veins matched in position and hypertrophied; stigma broad with both sides convex; triangles not traversed by cross veins. Ophiogomphus

*cc* Anal loop consisting normally of four cells; first and seventh antenodel cross veins matched in position and hypertrophied; stigma long and narrow with parallel sides; each triangle divided by a cross vein

Hagenius p. 440

*bb* Hind wings with no distinct anal loop, or with one consisting of a single cell

*c* Triangle of the fore wing one third shorter than that of the hind wing; generally a single cell between the bases of veins $A_2$ and $A_3$ .. Lanthus

*cc* Triangle of the fore wing less than one fourth shorter than that of the hind wing; generally, two or more cells between $A_2$ and $A_3$ at their origin

*d* Hind femora naked, or with numerous short spines

Gomphus, *sens. lat.* p. 443

*dd* Hind femora with five to seven long, strong spines

Dromogomphus p. 461

*Nymphs*

*a* Middle legs more approximate at the base than are the fore legs; fourth segment of the antenna slender, erect, about as long as the third segment is wide; 10th abdominal segment about as long as the ninth

Progomphus

*aa* Middle legs not more (usually less) approximate than the fore legs at base; the fourth segment of the antenna a mere rudiment, orbicular or discoid, much shorter than the third segment is wide; 10th abdominal segment much shorter than the ninth

*b* Wing cases strongly divergent on the two sides; lateral lobe of labium blunt at apex.......................................................Ophiogomphus

*bb* Wing cases laid closely parallel along the back; lateral lobe of labium ending in a sharp, incurved hook

*c* Abdomen very thin and flat, circular in outline as seen from above; third segment of antenna flat and subcircular.......................Hagenius

*cc* Abdomen less depressed, ovate to lanceolate in outline, at least twice as long as wide

*d* Third joint of antenna very flat, thin, and in outline circular or broadly oval..................................................Lanthus

*dd* Third joint of antenna elongate, linear, little flattened

*e* Dorsum of the ninth abdominal segment rounded, or with a low, obtuse, median longitudinal ridge.......................Gomphus, *sens. lat.*

*ee* Ninth abdominal segment with a sharp middorsal ridge, ending in a straight apical spine...............................Dromogomphus

The genus Progomphus has not yet been found in New York state, but it will probably be eventually. It ranges from Massachusetts southward and westward across the continent, a single P. obscurus Selys, having been taken in the whole northeastern United States.

### OPHIOGOMPHUS

Four species of this genus are known from New York state. A fifth, O. mainensis Packard is in our lists, but erroneously, I believe. The specimens on which the record is based are in the Lintner collection and in the museum of comparative zoology. I have examined them all, and they certainly belong to O. carolus Ndm., which I believe to be a distinct species. The error seems to have come in the associating of males of O. carolus from New York with the female type of O. mainensis. Our four species may be separated as follows.

#### KEY TO THE NEW YORK SPECIES

*Imagos*

*a* Sides of the middle and hind femora yellow; the inferior abdominal appendage of the male narrower than the superiors, not visible from above

*b* No black line on the third lateral suture (fig. 10) of the thorax; abdominal segments mostly yellowish or brownish, marked with black apically
rupinsulensis

*bb* Third lateral suture of the thorax black, middle abdominal segments black on the dorsal side.......................................................aspersus

*aa* Sides of the middle and hind tarsi black; the inferior, abdominal appendage of the male wider than the superiors, its lateral angles visible from above

*c* Forks of the inferior abdominal appendage of the male apparently again forked, the apex of each bearing two strong, upcurved teeth separated by a deep rounded notch...............................................johannus

*cc* Forks of the inferior abdominal appendage of the male ending bluntly, the obtuse angles bearing low teeth ................................ carolus.

For the differential characters of other North American species, see my paper "Ophiogomphus" in the *Canadian entomologist*, 1899, 31 : 233-38, pl. 5.

### Ophiogomphus rupinsulensis Walsh

1862 Erpetogomphus rupinsulensis Walsh, Acad. nat. sci. Phil. Proc. p. 388 (original description)

1890 Diastatomma rupinsulense Kirby, Cat. Neur. Odon. p. 61 (bibliography)

1892 Ophiogomphus rupinsulensis Banks, Am. ent. soc. Trans. 19 : 351 (listed)

1893 Ophiogomphus rupinsulensis Calvert, Am. ent. soc. Trans. 20 : 242 (description)

1894 Ophiogomphus rupinsulensis Banks, Can. ent. 26 : 77 (listed from Ithaca)

1895 Ophiogomphus rupinsulensis Calvert, N. Y. ent. soc. Jour. 3 : 44 (listed from Ithaca)

1897 Ophiogomphus rupinsulensis Calvert, N. Y. ent. soc. Jour. 5 : 93 (listed from Schoharie)

1897 Herpetogomphus pictus Needham, Can. ent. 29 : 181-82 (description)

1899 Ophiogomphus rupinsulensis Needham, Can. ent. 31 : 236, pl. 5, fig. 3, 12, 21, 30 and 31

1899 Ophiogomphus rupinsulensis Kellicott, Odon. Ohio, p. 53-54 (full description)

1900 Ophiogomphus rupinsulensis, Williamson, Dragon flies Ind. p. 298 (full description)

This handsome, widely ranging species has been taken at several places in the state. It was not met with at Saranac Inn. The nymph is unknown.

### Ophiogomphus aspersus Morse

1895 Ophiogomphus aspersus Morse, Psyche, 7 : 209 (original description)

1899 Ophiogomphus aspersus Needham, Can. ent. 31 : 236, pl. 5, fig. 2, 11, 20 and 29

This species, hitherto known from three somewhat immature specimens in the Museum of comparative zoology, was common at Saranac Inn. Many imagos of both sexes were observed flying over Little Clear creek in the places where the shallow current rippled over sand. The males would fly back and forth a few times and then rest for a time on some prominent twig near shore, generally on the higher bank. They were not difficult to approach or to capture when at rest. Except when oviposit-

ing, the females seemed to remain less of the time in the vicinity of the water. The female makes a succession of sweeps back and forth near the head of some little riffle, striking the water, after short flights, again and again near the same place, leaving her eggs in it.

Imagos, living and mature, are of a rich, deep green color with the usual oblique stripes of blackish brown. Unfortunately, the color fades readily, even where daylight is excluded. The few imagos which I took the time to gather were nearly all netted while resting on a water pipe which crosses a riffle just below the railroad bridge.

The nymphs were very common in the sandy bed of the creek. A great many were raked up and sifted out with a sieve net while collecting for other material. The cast skins were abundant along the banks through the months of June and July, sticking to whatever support offered, within a foot of the edge of the water.

**Nymph.** (pl. 18, fig. 5) Total length 27.5 mm; abdomen 17.5 mm; hind femur 5 mm; width of head 5 mm, of abdomen 7.5 mm.

Legs, genae, sides of the antennae, and lateral margins of the abdomen, hairy; the general dorsum nearly bare; well developed burrowing hooks at the apices of the fore and middle tibiae.

Abdomen oval in outline as seen from above, abruptly narrowed on the ninth segment; the 10th segment one third shorter than the ninth; the lateral abdominal appendages two thirds as long as the others; very short, subequal lateral spines on the seventh to the ninth segments; dorsal hooks represented on the second to ninth segments by blunt rudiments, which are erect on the front and posteriorly directed on the hind segments, each surmounting a low transverse ridge, which extends across the dorsum and disappears down on the sides on each segment. Anterior two thirds of each segment, including this ridge, prickly granulate; posterior third polished, shining, smooth.

Mentum of labium one third longer than wide, dilated beyond its basal third and upturned so as to be flaring upward at its edges; median lobe distinctly rounded and fringed with flat scales, and bordered besides with a row of low, broad, rectangular teeth; lateral lobe incurved, rounded on the apex and not bearing a terminal hook or sharp angle, its internal margin bordered with a row of 12 to 15 low teeth.

Color greenish or brownish, with paler and darker mottlings; apical pale rings on all femora; a pair of transversely elongate whitish spots on the dorsum of the seventh abdominal segment, repeated on the eighth segment, but there divided into two spots each side; a whitish spot each side of the 10th segment beside the base of the superior appendage; tips of all the abdominal appendages whitish.

The nymph is a rapid burrower, trailing along at slight depth through nearly clean sand under the currents, often leaving a faint line behind showing where the tip of the abdomen, upturned for respiration, has pushed the sand grains aside.

### **Ophiogomphus carolus** Needham

Plate 20, fig. 1-4, 6, 7

1897 Ophiogomphus carolus Needham, Can. ent. 29:183, pl. 7, fig. 1, 2, 3, 4, 6, 7

1899 Ophiogomphus carolus Needham, Can. ent. 31:235-36, pl. 5, fig. 1 and 28

This species, abundant at Ithaca N. Y. and taken at several other places in the state, was not met at Saranac Inn. It is a very secretive species, few imagos being seen, even where nymphs are excessively abundant. Like the preceding species, the nymphs prefer the sandy beds of running streams.

**Nymph.** Total length 26 mm; abdomen 17 mm; hind femur 4.5 mm; width of head 5 mm, of abdomen 7.5 mm.

Body moderately depressed, widest across the sixth abdominal segment, suddenly narrowed on the ninth segment. All ventrolateral margins closely fringed with soft hairs. Color yellowish, the surface abundantly sprinkled with brownish granulations visible under a lens.

Abdomen with lateral spines on segments 7-9, a little increasing in length posteriorly, but on the ninth segment distinctly shorter than the 10th segment. Dorsal hooks on these same segments developed as small blunt posteriorly directed prominences, which hardly surpass the narrow, bare apical band on their respective segments, longest on segment 9, and decreasing in size anteriorly so as to be barely represented on segments 6, 5, 4.

Labium as in O. aspersus, but with the 12 to 16 teeth on the inner margin of the lateral lobe a little longer and more angulate at tips.

Easily distinguished from the nymph of O. asperus by the unequal development of the dorsal hooks on the abdominal segments.

This species is very common at Ithaca N. Y. Few imagos have been taken at large, and, indeed, they are rarely met with; but the nymphs may be collected by hundreds from Six Mile creek in spring, and they are very easily reared.

### **Ophiogomphus johannus** Needham

Plate 20, fig. 5

1897 Ophiogomphus johannus Needham, Can. ent. 29:182, pl. 7, fig. 5

1899 Ophiogomphus johannus Needham, Can. ent. 31:235, pl. 5, fig. 9, 18 and 27

The type of this species in the Cornell university collection is from Wilmurt N. Y., and was collected by Prof. J. H. Comstock. Since describing this somewhat immature specimen, I have seen specimens collected in Maine by Prof. Harvey, and in western Pennsylvania by Mr Williamson. From these I learn that the terminal abdominal appendages of the male are not well represented in the figures I have published.[1]

1 Can. ent. 1897. 29:182, pl. 7, fig. 9, 18.

The superiors are well enough (and in these the chief distinctions between this species and O. carolinus Hagen lie), but the inferior is incorrect. It is shrunken in the type from which the figure was drawn; it should be shown almost exactly as in O. carolinus, which is correctly represented in fig. 8 and 17 of the same plate. Mature specimens show also a deep green color on the thorax, and often, the humeral and antehumeral stripes of blackish brown entirely separated at their upper ends.

The cast skin, pinned with the type, is not in fit condition for description, and the nymph is therefore practically unknown.

### HAGENIUS

There is a single North American species.

## Hagenius brevistylus Selys

1854 Hagenius brevistylus Selys, Acad. Belg. (2) Bul. 21:82

1861 Hagenius brevistylus Hagen, Synopsis Neur. N. Am. p. 114

1890 Hagenius brevistylus Kirby, Cat. Neur. Odon. p. 75 (bibliography)

1890 Hagenius brevistylus Beutenmüller, Dragon flies vs mosquitos. p. 163 (listed from vicinity of New York)

1892 Hagenius brevistylus Banks, Am. ent. soc. Trans. 19; 352 (listed)

1893 Hagenius brevistylus Calvert, Am. ent. soc. Trans. 20; 241 (description)

1894 Hagenius brevistylus Banks, Can. ent. 26:77 (listed from Ithaca)

1895 Hagenius brevistylus Calvert, N. Y. ent. soc. Jour. 3; 44 (review of lists)

1899 Hagenius brevistylus Kellicott, Odon. Ohio, p. 52–53 (good description)

1900 Hagenius brevistylus Williamson, Dragon flies Ind. p. 282–83 (good description)

*Nymph*

1872 Hagenius brevistylus Cabot, Immature state Odon. pt 2, p. 9, pl. 3, fig. 4

1885 Hagenius brevistylus Hagen, Am. ent. soc. Trans. 12; 279–80 (very full description)

1897 Hagenius brevistylus Needham, Can. ent. 29:168 (characters stated in table for gomphine nymphs)

This big species frequents clear streams, and is common throughout New York state. It is very striking as an adult on account of its great size and black color, and its nymph (pl. 18, fig. 7) is a most grotesque creature.

At Saranac Inn the species was common along Little Clear creek. The nymphs were found in the midst of the trash on the bed of the stream, and, during the season of transformation, exuviae dotted the banks rather conspicuously. Few imagos were seen at large. These fly swiftly from one resting place to another about the stream. They are

easy to approach and proved not very difficult to capture with a net, when resting on the bridges crossing the stream.

The eggs are dropped by the female during flight. She descends and strikes the water repeatedly, at points wide apart: 10 to 20 eggs are liberated at each descent. Thus they are well distributed. Each egg (pl. 19, fig. 2) is somewhat spindle formed in outline with rounded ends, at first of whitish color, becoming yellowish after a few hours. The ovaries of a teneral female from a breeding cage contained no eggs that were nearly mature; a considerable time must elapse after transformation before oviposition can take place.

Nymphs of various sizes are always found together. These sizes fall into three or more possible groups of sizes, which may indicate a developmental period of four or more years duration. In other localities I have observed that the nymphs are likely to be found about the deep holes in the creek bed, under lodged driftwood, etc.; but in Little Clear creek they were found everywhere. Even in the shallow fish ponds made by impounding the creek they were so common on the bottom that one or more could be taken anywhere at almost every haul of the sieve net. 11 exuviae were picked from the boarded side of one of the ponds in a distance of 20 yards.

The nymph has been well described by Hagen and figured by Cabot (*ll. cc.*). There is no need of repeating the description here, since it will be at once recognized by plate 18, figure 7, and by the characters given in the table.

### LANTHUS

This genus includes the smallest and the daintiest of our Gomphinae, black species, striped with green. Its two species probably both occur within the state of New York, though but one of them, L. parvulus, has been recorded for the state hitherto. They may be easily distinguished as follows.

Abdominal appendages black .................................. parvulus
Abdominal appendages yellow or whitish ...................... albistylus

## **Lanthus parvulus** Selys

1854 Gomphus parvulus Selys, Acad. Belg. (2) Bul. 21 : 56
1857 Gomphus parvulus Selys, Monographie des Gomphinae, p. 157
1861 Gomphus parvulus Hagen, Synopis Neur. N. Am. p. 109
1890 Aeshna parvula Kirby, Cat. Neur. Odon. p. 65 (bibliography)
1892 Gomphus parvulus Banks, Am. ent. soc. Trans. 19 : 352 (listed)
1893 Gomphus parvulus Calvert, Am. ent. soc. Trans. 20 : 242 (description)

1894 Gomphus parvulus Banks, Can. ent. 24:77 (recorded from Ithaca)
1895 Gomphus parvulus Calvert, N. Y. ent. soc. Jour. 3:44 (recorded from Ithaca)
1897 Gomphus parvulus Needham, Can. ent. 29:165, 166, 167 (made the type of a new genus, Lanthus: nymph, found at Ithaca N. Y. identified with those described by Dr Hagen from Rocky creek Ky. in Trans. Am. ent. soc. 1885, 12:281 and doubtfully referred by him to Uropetala (Tachopteryx) thoreyi: nymph figured, pl. 7, fig. 8–10)

The habits of the imagos of this species are unknown. The few specimens I was able to obtain at Ithaca in 1897 were all bred, and I saw no imagos at large. The nymphs are very interesting little fellows, quite as different in certain habits as they are in structure and appearance from other gomphines. They seem to prefer little, trickling streams fed by springs, and burrow in beds of sand in the deeper parts. They are more agile than other gomphine nymphs, burrow more rapidly, and, when withdrawn from the water, unlike others, they feign death, and lie quite still for a number of minutes. On account of this habit, as well as on account of the mottled coloration of the body, they are much more difficult to detect while collecting than are the others which begin active struggling as soon as the net is lifted above the water.

**Nymph.** (Pl. 18, fig. 6 and 20, fig. 8–10) Total length 23 mm; abdomen 14 mm; hind femur 5 mm; width of head 5 mm, of abdomen 6 mm.

Body somewhat depressed, a little hairy on the genae and on the tibiae, elsewhere bare; head concave on the hind margin; antennae, with the two basal segments short and angular, the first a little larger, the articulation between the first and second a little oblique, the third segment obliquely oval, flat, one third longer than wide, with a depressed smooth oval area within the scurfy pubescent marginal rim, the fourth segment a minute round rudiment, at the inner apical angle of the third; labium mentum a little longer than broad, its front border appearing convex by the rounded fringe of scales, in the midst and at the base of which are four to six brown, minute quadrangular teeth; lateral lobe little arcuate, the distal angle produced and inclined internally, but hardly differentiated from the six teeth on the inner margin, these teeth all largest in the middle, and a line connecting their summits would be convex internally.

Abdomen stocky, widened to the seventh segment, and thereafter narrowed, most narrowed on the ninth segment; no dorsal hooks at all, but a median impressed line ending on the seventh segment; lateral spines well developed on segments 8 and 9, on 9 broadly triangular, and considerably shorter than the 10th segment, against the sides of which they are closely applied; 10th segment one half as long as the eighth, one third as long as the ninth, three fifths as long as the superior and inferior appendages; three fourths as long as the others.

## Lanthus albistylus Selys

1878 Gomphus albistylus Selys, Acad. Belg. (2) Bul. 46:460 (original description of ♀ from Maine)

1878 Gomphus naevius Acad. Belg. (2) Bul. 46:462 (original description of ♂ from Pennsylvania)

1890 Aeshna albistyla Kirby, Cat. Neur. Odon. p. 66 (bibliography)

1890 Aeshna naevius Kirby, Cat. Neur. Odon. p. 66 (bibliography)

1892 Gomphus albistylus Am. ent. soc. Trans. 19:351 (listed)

1892 Gomphus albistylus Banks, Am. ent. soc. Trans. 19:352 (listed)

1893 Gomphus albistylus Calvert, Am. ent. soc. Trans. 20:242 (description)

1898 Gomphus albistylus Harvey, Ent. news. 9:63–65 (description, figure and notes)

Still known only from Maine and Pennsylvania, in which states, however, Prof. F. L. Harvey and E. B. Williamson, respectively, have collected a goodly number of specimens of both sexes. There is in the Cornell university collection a specimen lacking half the abdomen, probably of this species, from North Carolina. The nymph is not known (unless the ones described by Hagen should prove to be of this species, instead of L. parvulus, as I have supposed. I have not compared my own nymphs with Hagen's types).

### GOMPHUS

The United States is the center of abundance for this great genus, and it is nowhere better represented than in New York state. Our list includes 17 regional species, only two of which have not yet been actually taken in the state. They are species of medium or large size, often very local, and locally very abundant. They are found about water, and in woods and copses adjacent to it. They are often flushed from a bare path or roadway; they are perhaps most commonly seen resting flat on the surface of some log which stretches its length across a stream; they rarely perch atop a slender twig after the manner of the skimmers (libellulines). Our species fly mainly in June, though G. scudderi is a midsummer, and G. spiniceps a late summer species.

The nymphs form a most important part of the bottom fauna in all clear waters. They are active burrowers, taking their prey either on or beneath the surface of the bottom silt. They are very rapacious, and will eat almost any living animals small enough to be held by their powerful grasping labia. The nymphs are highly specialized for their peculiar life. They are more unlike than are the imagos, and in general more

easily referable at a glance to their place in the genus. The imagos exhibit with slight variations one color pattern, one plan of venation, one habitus, and are therefore not easy to distinguish. I give below an artificial key to aid in the recognition of our species, and follow it with a synoptic arrangement of the genus, in which is included a statement of the more important characters of lesser groups within the genus. For all of these I prefer to retain the old generic name Gomphus till more of the nymphs are known.

## ARTIFICIAL KEY TO IMAGOS

1 Face entirely yellow .......... 2
  Face yellow, transversely banded with black .......... 10
  Face suffused with brownish black; large, very elongate species, with a distinct anal loop of a single cell, a pair of narrow oblique yellow stripes on the dark background of the thoracic dorsum .......... 14
2 Hind margin of the occiput with a distinct median tooth ..... villosipes
  " without " .......... 3
3 Tibiae yellow externally .......... 4
  " black " .......... 7
4 Abdominal segments 7–9 strongly dilated about as wide as the thorax fraternus
  Abdominal segments 7–9 little dilated, much narrower than the thorax... 5
5 Length under 45 mm .......... exilis
  Length over 45 mm .......... 6
6 Superior abdominal appendages of the male with a sharp inferior tooth; vulvar lamina of the female composed of two acute triangular lobes, one fourth as long as the ninth segment .......... spicatus
  Superior abdominal appendage of the male with a low inferior lobe; vulvar lamina of the female composed of two low rounded lobes, and hardly longer than one 10th of the ninth segment .......... sordidus
7 Length under 40 mm .......... abbreviatus
  Length over 40 mm and under 50 mm .......... 8
  Length over 50 mm .......... 9
8 Abdominal segments 7–9 greatly dilated, as wide as the thorax ventricosus
  Abdominal segments 7–9 little dilated, much narrower than the thorax quadricolor
9 Dorsum of the 10th abdominal segment and the superior appendages black .......... descriptus
  Dorsum of the 10th abdominal segment and the superior appendages yellow .......... furcifer
10 Yellow of the thoracic dorsum reduced to two narrow, oblique, isolated, yellow stripes .......... scudderi
  Yellow stripes of the thoracic dorsum broader, not isolated, dilated at their anterior ends .......... 11
11 Side (anterior face) of the hind femora yellow .......... amnicola
  Sides of the hind femora black .......... 12

12 Two cells between veins $A_1$ and $A_2$ at their origin; length less than 45 mm ........ brevis
A single cell between veins $A_1$ and $A_2$ at their origin; length more than 45 mm ........ 13
13 Midlateral thoracic stripe complete: length about 46 mm ........ adelphus
Midlateral thoracic stripe interrupted, not extending above the spiracle: length about 54 mm ........ vastus
14 Ninth abdominal segment little longer than the eighth, ground color brown ........ plagiatus
Ninth abdominal segment much longer than the eighth; ground color black ........ spiniceps

### SYNOPTIC ARRANGEMENT OF THE GENUS, IMAGOS AND NYMPHS

#### Subgenus GOMPHUS

*Imago.* Generally with two cells between veins $A_1$ and $A_2$ at their origin, when with but one, that one generally longer (in the axis of the wing) than wide, and never so thickened in its bordering veins as to constitute a distinct anal loop; hind femora similar in the two sexes; posterior genital hamule in the male generally nearly vertical in direction, at least not directed anteriorly; eighth abdominal segment generally squarely cut, rarely a very little longer on the dorsal than on the ventral side.

*Nymph.* Abdomen wider than the head; lateral spines on abdominal segments 6–9; an impressed middorsal line on abdomen more or less evident, often appearing to divide the segments longitudinally, present even on the bases of segments which may bear dorsal hooks apically; median lobe of labium straight on anterior border, or very slightly convex, and not bearing a median tooth.

A synthetic group, offering evident points of departure for the three subgenera which follow it.

KEY

1) Ninth abdominal segment a little shorter than the eighth; two cells between veins $A_1$ and $A_2$ at their origin; male with the fork of the inferior abdominal appendage not extending laterally beyond the superiors; female with a low carina on the vertex, at whose extremities arise black thornlike spines; small species.

*a*) *Imago* Face yellow: *Nymph* Length when full grown 24 mm; lateral spine on the sixth abdominal segment less than half the length of the one on the seventh segment ........ G. abbreviatus

*aa*) *Imago* Face transversely lineate with black. *Nymph* Length when full grown 26 mm; lateral spine on the sixth abominal segment more than half as long as the one on the seventh segment ........ G. brevis

2) Ninth abdominal segment as long as the eighth, or often a very little longer; inferior abdominal appendage of the male widely forked, its

apices appearing at the sides of the superiors; female generally without thornlike vertical spines.

*a*) *Imago* A single cell between veins $A_1$ and $A_2$ at their origin; segments 8 and 9 of abdomen of about equal length, 7–9 greatly dilated, in width almost equaling the thorax; vulvar lamina of the female about half as long as the ninth abdominal segment. *Nymph* with a broad, obtusely pointed abdomen; lateral spines on the ninth abdominal segment twice as long as the 10th segment, the latter segment thus appearing incased in the ninth; median impressed line on abdomen distinct, and no dorsal hooks except the merest rudiments on segments 8 and 9.

*b*) Face of *imago* lineate with black. Length of full grown *nymph* 29mm.................................................. G. adelphus

*bb*) Face of *imago* entirely yellow. Length of full grown *nymph* 33 mm.................................................. G. fraternus

*aa*) *Imago* Normally two cells between veins $A_1$ and $A^2$ at their origin; ninth abdominal segment a little longer than eighth; segments 7–9 less dilated; vulvar lamina of female one third to one 10th as long as the ninth segment. *Nymph* with lanceolate, pointed abdomen; the lateral spines on the ninth segment generally shorter than the 10th segment and not inclosing it; dorsal hooks represented by rudiments of some of the segments before the eighth; impressed middorsal line visible only toward the bases of the middle segments.

*b*) *Imago* Length 45 mm; legs all black; *nymph* unknown G. quadricolor

*bb*) *Imago* Length over 50 mm; fore femora yellow or green below; *nymph* with very low, obtuse, inconspicuous rudiments of dorsal hooks.

*c*) *Imago* Tibiae black externally; inferior abdominal appendage male with an inferior tooth; vulvar lamina of the female about one third the length of the ninth abdominal segment. *Nymph* with about eight to 10 teeth on the inner margin of the lateral lobe of the labium G. descriptus

*cc*) *Imago*. Tibiae yellow externally; superior abdominal appendage of the male with an obtuse inferior lobe; vulvar lamina of the female about one 10th as long as the ninth abdominal segment. *Nymph* with about six to eight teeth on the inner margin of the lateral lobe of the labium.............................. G. sordidus

*bbb*) *Imago* Length about 48 mm; tibiae yellow externally; yellow on the dorsum of abdominal segments 9 and 10. *Nymph* with pointed rudimentary dorsal hooks on segments 6–9................ G. exilis

## Subgenus GOMPHURUS

*Imago*. A single cell between veins $A_1$ and $A_2$ at their origin, having a thickened margin, forming an anal loop; abdominal segments 7–9 greatly dilated, as wide as or wider than the thorax: eighth segment cut squarely on apex; posterior hamule of male perpendicular; hind femora similar in the two sexes.

*Nymph.* Abdomen a little wider than the head, the ninth segment hardly longer than the eighth; lateral spines on segments 6–9, a well marked middorsal impressed line extending to the eighth segment, and very minute rudiments of dorsal hooks on segments 8 and 9; tibial burrowing hooks large; front border of median lobe of labium straight, lateral lobe with its terminal hook bent inward at almost or quite a right angle; apex of abdomen regularly narrowed beyond the middle.

KEY

*a*) *Imago* Face entirely yellow; *nymph* unknown...... G. ventricosus

*aa*) *Imago* Face with narrow black lines on sutures; sides of hind femora yellow; *nymph* unknown............................G. amnicola

*aaa*) *Imago* Face with broad transverse bands of black; hind femora black; abdominal segments with basal rings of yellow; *nymph* with the lateral spines of the ninth segment less than half as long as the 10th segment G. scudderi

*aaaa*) *Imago* Face with broad transverse bands of black; hind femora black; yellow of middle abdominal segments restricted to triangular spots on the dorsum; *nymph* with the lateral spines of the ninth segment about as long as the 10th segment.............................. G. vastus

## Subgenus STYLURUS

*Imago.* A single cell between veins $A_1$ and $A_2$ at their origin, that cell strongly bordered; abdominal segments 7–9 not greatly dilated (much narrower than the thorax), but considerably elongated; eighth segment cut squarely at apex; posterior genital hamule of male strongly directed anteriorly; hind femora similar in the two sexes.

*Nymph.* Abdomen narrower than the head, and greatly elongated; tibial burrowing hooks very small; lateral spines, middorsal suture and dorsal hooks of abdomen as in Gomphurus; ninth abdominal segment longer than the eighth, sometimes twice as long.

KEY

*a*) *Imago.* Ninth abdominal segment of imago much shorter than the seventh. *Nymph* with the lateral spines of the ninth abdominal segment longer by half than the 10th segment............ G. plagiatus

*aa*) *Imago* with segments 7 and 9 of abdomen about equal in length. *Nymph* with the lateral spines of the ninth abdominal segment shorter by half than the 10th segment.................................. G. spiniceps

## Subgenus ARIGOMPHUS

*Imago.* Two cells between the base of veins $A_1$ and $A_2$ at their origin; eighth abdominal segment obliquely cut at apex, longer on the dorsal side; hind femora different in the two sexes, in the male hairy, and in

the female armed with numerous stout spines below; posterior hamule of male directed posteriorly.

*Nymph.* Abdomen wider than the head; flattened, lanceolate pointed, suddenly narrowed on the ninth segment, which is longer than its apical width; no impressed middorsal line, instead, a ridge without distinct dorsal hooks; lateral spines on segments 7–9 or 8–9, none on segment 6; median lobe of labium prominently rounded or dome shaped, and usually bearing, besides the usual brush of flattened hairs, a median tooth.

KEY

*a*) *Imago* with abdominal appendages black; superiors of male with an inferior tooth; *nymph* with bare median narrow ridge on the abdomen; lateral spines on segments 7–9 .......................... G. spicatus

*aa*) *Imago* with a tooth in the middle of the occipital border. Abdominal appendages yellowish, no inferior tooth on the male superiors. *Nymph* with an obtuse scurfy or rough pubescent middorsal ridge on the abdomen; lateral spines on segments 7–9 .................... G. villosipes

*aaa*) *Imago* with no tooth in middle of hind border of the occiput; abdominal appendages yellow; male superior appendages apparently bifurcated at apex; *nymph* unknown .................................... G. furcifer

## Gomphus abbreviatus Selys

1878 Gomphus abbreviatus Selys, Acad. Belg. (2) Bul. 46:464 (original description)

1890 Aeshna abbreviata Kirby, Cat. Neur. Odon. p. 66 (bibliography)

1892 Gomphus abbreviatus Banks, Am. ent. soc. Trans. 19:351 (bibliography)

1893 Gomphus abbreviatus Calvert, Am. ent. soc. Trans. 20:243 (description)

This species is not recorded from New York state. In June of 1897 I found some nymphs at Ithaca N. Y. in Fall creek opposite the Cornell insectary, and bred a few of them. The imagos I did not observe at large. Nothing has been written as to their habits. The species appears to be distributed through the northeastern states as far south as Pennsylvania. It was not found at Saranac Inn.

**Nymph.** Measures in length 23–24 mm; abdomen 14 mm; hind femur 5 mm; width of head 5 mm, of abdomen 6.5 mm. It differs from G. brevis nymph only in size and in the relative length of the foremost lateral spines on the abdomen, characters already stated in the table; there is no need, therefore, of a separate description of it, since G. brevis is described in full below, and the description would be but repetition of the characters stated for that species. I will therefore add but a note as to the differences of the situations in which I found the two nymphs: abbreviatus in the rocky basins of a gorge traversed by a foaming creek, destitute of the commoner large aquatic plants; brevis, in the bed of a reed-choked, slow flowing, upland stream.

### Gomphus brevis Hagen

1854 —— —— Emmons, Agric. N. Y. v. 5, Insects, pl. 15, fig. 2. (colored figure, no name or description)
1878 Gomphus brevis Hagen, Acad. Belg. (2) Bul. 46:461 (original description)
1890 Aeshna brevis Kirby, Cat. Neur. Odon. p. 66. (listed)
1892 Gomphus brevis Banks, Am. ent. soc. Trans. 19:351 (listed)
1895 Gomphus brevis Calvert, N. Y. ent. soc. Jour. 3:45
1897 Gomphus brevis Calvert, N. Y. ent. soc. Jour. 5:93

This species, originally described from specimens obtained by Dr Lintner at Schoharie N. Y., was common at Saranac Inn. I captured but a single imago, and saw but few, but the nymphs were very plentiful in Little Clear creek. The few imagos seen flitted about the edge of the water in the warm sunshine in a manner very similar to that of other small gomphines; oviposition was not observed.

The season of transformation was apparently about ended on our arrival at Saranac Inn in the middle of June; exuviae which I, having bred abbreviatus before, was able at once to refer to this species were thickly sprinkled over the boards on the sides of the fish ponds made by impounding the creek. I collected many of them during the first two or three days of our stay; thereafter but few additional exuviae appeared, the season being past. The species was not bred, but there can be scarcely a doubt that the nymphs, referred to it here by supposition, belong to it.

The original description of this species is not generally accessible in this country; no other has been published, apparently. Therefore, believing that an accessible English description will be of service to some, I give a brief one below, and follow it with a description of the nymph, hitherto unknown.

**Imago.** Measures in total length 42–45 mm; abdomen 30–33 mm; hind wing 25–27 mm.

Colors black and green; face with heavy black lines on all its sutures and margins, these lines sometimes overspreading the whole face except the upper part of the frons and the sides of the post-clypeus and the labium; rear of the frons, all of the vertex (excepting the tips of its horns), and the front and lateral margins of the occiput black; the occiput otherwise clear yellow, distinctly wider and more convex in the female.

Middorsal thoracic stripe short, with parallel sides, narrowed to a median line before the collar, divided by a yellow carina; humeral and antehumeral stripes contiguous near their upper ends, leaving an isolated yellow triangular spot above, and an isolated narrow line below between them; midlateral thoracic stripe incomplete above, disappearing above the spiracle; stripe on the third lateral suture complete but narrow; legs all black (♂) or with the front femora green beneath (♀).

Wings hyaline; costa black; stigma brown.

Abdomen black with a middorsal line of yellow triangles pointing posteriorly, elongate and twice constricted on the basal segments, becoming very short and restricted to the base on several segments before the ninth, and entirely absent from the ninth and 10th segments. There is a line of yellow at the extreme apex of some of the terminal segments beyond the spiniferous, apical, transverse carina; the 11th segment, "anal tubercle," of the female yellow except at the sides; appendages black; sides of segments 1–3 mainly yellow; segments 4–7 with small basal lateral yellow spots in the female; the slightly expanded lateral margins of segments 8 and 9 yellow in both sexes.

Described from a ♀ from Saranac Inn taken July 2, 1900, and from a ♂ collected on Mt Tom in Massachusetts; the larger measurements are for the female specimen.

This Saranac Inn female was the first imago seen there, and it will be noted that the date is two weeks after the nymphs had ceased emerging. I think this time represents the period necessary for the maturation of the eggs after transformation. A similar lapse of time between the period of transformation and that of oviposition was observed in the case of a number of other gomphines. I believe these insects live longer as imagos than is commonly supposed. As is well known, they will die within a week after transformation if kept in confinement, but apparently no one has tried feeding them well while keeping them as yet. May they not die of starvation?

**Nymph.** Pl. 18, fig. 3. Total length 26 mm; abdomen 17 mm; hind femur 5 mm; width of head 5 mm, of abdomen 6.5 mm.

Body depressed, abdomen with sides parallel to the eighth segment, then rather abruptly narrowed to an obtuse point; lateral spines on segments 6–9, the margins which bear them thin, and on the ninth segment finely spinulose serrate; spines of the ninth segment about as long as the 10th segment; very minute rudiments of dorsal hooks on segments 8 and 9; before the eighth segment there is an observable trace of the median impressed longitudinal line of the typical Gomphus nymph. The 10th segment is about one third the length of the ninth.

The mentum of the labium is rather short, little longer than broad; the lateral lobe is very moderately arcuate, its apex forming a short end hook not greatly differentiated from the teeth before it; of these teeth on the inner margin of the lateral lobe there are eight or nine, unequal, the middle ones being slightly largest, angulate, sharp, the line of their apices being convex internally, rather than concave, as in all the following members of the genus.

The color, usually obscured by dirt excepting after molting, is greenish brown, with darker mottlings arranged in transverse bands on abdominal segments, scars on abdomen surrounded with paler color.

The third antennal segment is linear, a little depressed and widened apically, hairy, as is usual, on the margins.

## Gomphus fraternus Say

1839 A e s c h n a f r a t e r n a Say, Acad. nat. sci. Phil. Jour. 8: 16
1861 G o m p h u s f r a t e r n u s Hagen, Synopsis Neur. N. Am. p. 104
1862 G o m p h u s f r a t e r n u s Walsh, Acad. nat. sci. Phil. Proc. p. 393
1863 G o m p h u s f r a t e r n u s Walsh, Ent. soc. Phil. Proc. 2: 238
1890 A e s h n a f r a t e r n a Kirby, Cat. Neur. Odon. p. 66 (bibliography)
1892 G o m p h u s f r a t e r n u s Banks, Am. ent. soc. Trans. 19: 352 (listed)
1894 G o m p h u s f r a t e r n u s Banks, Can. ent. 26: 77 (listed from Ithaca)
1895 G o m p h u s f r a t e r n u s Calvert, N. Y. ent. soc. Jour. 3: 45 (listed from Ithaca)
1897 G o m p h u s f r a t e r n u s Van Duzee, N. Y. ent. soc. Jour. 5: 89 (listed from Niagara)
1897 G o m p h u s f r a t e r n u s Calvert, N. Y. ent. soc. Jour. 5: 93 (listed)
1899 G o m p h u s f r a t e r n u s Kellicott, Odon. Ohio, p. 59 (description and figures)
1900 G o m p h u s f r a t e r n u s Williamson, Dragon flies Ind. p. 289 (description and figures)
1897 G o m p h u s f r a t e r n u s Needham, (nymph) Can. ent. 29, pl. 7, fig. 11 and 12 (figures only; those are reproduced in plate 20 of this bulletin)

This vigorous species seems to prefer the larger bodies of water. The imago is a very strong flyer. It skirts the edge of streams with dashing sweeps which seem to proclaim it master of the situation. I have several times seen it feeding on other dragon flies as large as M e s o t h e m i s s i m p l i c i c o l l i s. The nymph is an active burrower in the bare clay bottoms of streams and lakes under water of considerable depth. I repeat herewith the figures of the nymph (cited above) and add a brief description.

**Nymph.** Length 31 mm; abdomen 20; hind femur 6.5; width of head 5, of abdomen 9; colors obscured; margins all hairy; tibial burrowing hooks very strong, as long as tibia is wide. Third segment of antenna twice as long as the first and second together, hairy on margins; fourth a minute ovoid rudiment.

Mentum of labrum (pl. 20, fig. 12) squarish before the contracted basal fourth; median lobe very slightly convex, densely fringed; lateral lobe bluntly angular at the apex with 7–11 small teeth on inner margin.

Abdomen (pl. 20, fig. 11) broad, depressed, with sides parallel most of its length, abruptly narrowed beyond the sixth segment, minute dorsal hooks on segments 8 and 9; median groove on anterior segments, well developed lateral spines on segments 6–9 those of 9 about equaling the appendages.

## Gomphus adelphus Selys

1857 G o m p h u s a d e l p h u s Selys, Monographie des gomphines, p. 413
1861 G o m p h u s a d e l p h u s Hagen, Synopsis Neur. N. Am. p. 104
1896 A e s h n a a d e l p h a Kirby, Cat. Neur. Odon. p. 67 (bibliography)
1892 G o m p h u s a d e l p h u s Banks, Am. ent. soc. Trans. 19: 351 (listed)

1895 Gomphus adelphus Calvert, N. Y. ent. soc. Jour. 3:45 (listed from Bethlehem)

1897 Gomphus adelphus Calvert, N. Y. ent. soc. Jour. 5:93 (listed from Kenwood)

The specimens above described and listed were collected in New York state by Drs Fitch and Lintner. The species is also known from Massachusetts. I have not met with it in either immature or adult stage, and know nothing of its habitat or habits.

Dr Hagen has carefully described a nymph from Cambridge Mass., referable by supposition to this species in the Trans. Am. ent. soc. 1885, 12:262. If the nymph be full grown, as he thought, there can be but little doubt that it belongs to this species. However, his description agrees in every point excepting size with G. fraternus bred by me in Illinois. Unfortunately I did not get time while in Cambridge for the comparison of my own nymphs with Hagen's types. I have stated the difference in size in the foregoing table. These being all the differences known to me, I have nothing farther to add concerning this species.

### Gomphus quadricolor Walsh

1863 Gomphus quadricolor Walsh, Ent. soc. Phil. Proc. 2:246

1890 Aeshna quadricolor Kirby, Cat. Neur. Odon. p. 66 (bibliography)

1892 Gomphus quadricolor Banks, Am. ent. soc. Trans. 19:352 (listed)

1899 Gomphus quadricolor Kellicott, Odon. Ohio, p. 58 (description and figures)

1900 Gomphus quadricolor Williamson, Dragon flies Ind. p. 288-89 (description and figures)

This species is abroad during the first two weeks of June. It has not hitherto been reported from New York state, but I have seen a specimen collected near Ithaca. The nymph is unknown. I have not seen the imago alive. Prof. Kellicott wrote of it, "It rests on rocks projecting from rapids, or on the banks near by the most rapid parts of streams." (Odon. Ohio, p. 58)

### Gomphus descriptus Banks

1896 Gomphus descriptus Banks, N. Y. ent. soc. Jour. 4:195 (from Ithaca)

1897 Gomphus descriptus Calvert, N. Y. ent. soc. Jour. 5:95 (listed)

1900 Gomphus descriptus Williamson, Dragon flies, Ind. p. 293 (description and figures)

1897 Gomphus descriptus Needham, Zool. bul. 1:103-13 (digestive epithelium)

This species is quite abundant at Ithaca, and has not as yet been reported from any other locality. It flies during the latter part of May and the first week of June. I found a meadow beside a patch of woods

a favorite foraging ground for the adults; May 30, 1897, and for several days thereafter, they were flitting about this meadow in numbers, but were so active that it required some time to capture many specimens. I collected once enough nymphs to fill a quart fruit jar from Six Mile

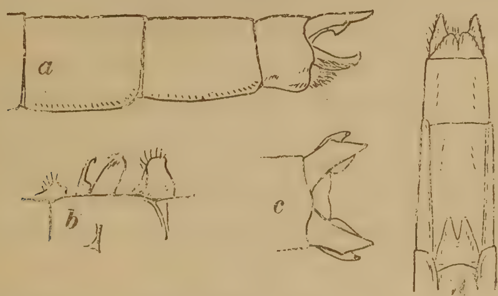


Fig. 11 Genitalia of Gomphus descriptus Banks. *a* lateral view of end of abdomen of male; *b* lateral view of the genital hamules of the male (inverted position); *c* dorsal view of the terminal abdominal appendages of the male; *d* ventral view of the vulvar lamina and end of abdomen of female

creek near Ithaca in an hour. I will mention a variety of this species which occurred at Saranac Inn, before describing the nymph. I bred the species at Ithaca and collected the variety at Saranac Inn, but am unable to find any differences between them in the immature stages; the description will therefore stand for both.

G. descriptus borealis n. var. This is the dragon fly figured by Hagen in Selys's *Monographie des Gomphines* (pl. 9, fig. 2, dorsal view)

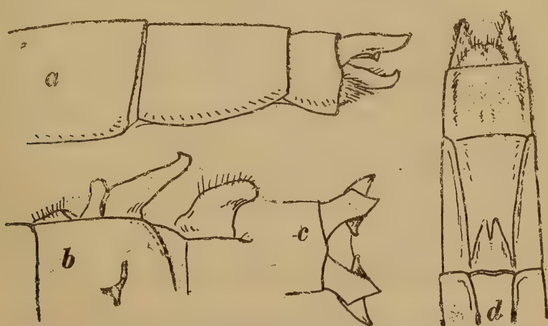


Fig. 12 Gomphus descriptus borealis *n. var.* Lettering as in fig. 11

as Gomphus spicatus. There are several points of difference between this insect and G. spicatus, one of the most obvious of which is the yellow color of the external face of the tibiae in spicatus. The appendages and the proportions of the apical segments of the abdomen are different.

The variety differs from the typical descriptus, so far as observed, only in the form of the appendages of the male abdomen. These differences are shown in the accompanying figures, wherein it will be seen there is a radical difference in the form of the anterior hamule of the male, and that in the variety the superior appendage is shorter, less acute at apex and with the inferior tooth directed more inward than in the typical descriptus.

The variety was first received from Franconia N. H. among some specimens sent me by Mrs Annie Trumbull Slosson. It was not uncommon about Saranac Inn. A few were observed foraging about the Otisville road, and a few others were seen resting on the bare sand of the railroad embankment at the outlet of Little Clear pond. Oviposition was not observed.

**Nymph.** (Pl. 18, fig. 4) Total length 32 mm; abdomen 20 mm; hind femur 5.6 mm; width of head 5 mm, of abdomen 7 mm.

Body depressed, lanceolate, hairy on all lateral margins, tapering beyond the middle of the rather pointed abdomen. Colors generally entirely obscured by adherent dirt, but after molting there is often seen a darker band across the base of each abdominal segment.

Third segment of the antenna depressed and somewhat widened apically.

Labium with the mentum one third longer than wide; median lobe nearly straight on its front border, fringed with flat hairs, but unarmed; lateral lobe regularly incurved with a long terminal hook, exceeding the six to eight teeth before it on the inner margin.

Lateral spines on abdominal segments 6–9, sometimes obscured by tufts of hairs on the sixth segment, those of the ninth segment short, hardly surpassing the base of the 10th segment, straight, but not closely appressed. 10th segment half as long as the ninth, and a little shorter than the appendages; lateral appendages a sixth to a seventh shorter than the others. Dorsal hooks represented by low, inconspicuous rudiments on segments 3–9, with traces of the median impressed line on the anterior end of the middle segments.

Nymphs of this species were taken at two places: Colby pond, just west of the town of Saranac Lake, and Bone pond. They were associated with and greatly outnumbered by G. spicatus in both places.

## Gomphus sordidus Hagen

1854 Gomphus sordidus Hagen, Acad. Belg. (2) Bul. 21 : 54
1861 Gomphus sordidus Hagen, Synopsis Neur. N. Am. p. 106
1875 Gomphus lividus Hagen, Bost. soc. nat. hist. Proc. 18 : 45 (listed)
1893 Gomphus minutus Calvert, Am. ent. soc. Trans. 20 : 244 (♀ only)
1899 Gomphus lividus Kellicott, Odon. Ohio, p. 66 (description and figures)

1897 Gomphus umbratus Needham, Can. ent. 29: 184 (described, from Ithaca)

1900 Gomphus sordidus Williamson, Dragon flies Ind. p. 292

There are plenty of descriptions and figures of this troublesome species, as will be seen from the above bibliography. I found both imagos and nymphs associated with the same stages of G. descriptus Banks at Ithaca. It is entirely similar to that species in habits, and in appearance, but will be readily distinguished by the characters given in the tables. The nymph is not easy to distinguish, however; in fact, I find it necessary to make a microscopic examination of the labium before being sure as to the species. I bred a good many specimens at Ithaca. By way of description, I will only say that it is entirely similar to the nymph of descriptus, so far as known to me, excepting in the differential character stated in the table.

### Gomphus exilis Selys

1854 Gomphus exilis Selys, Acad. Belg. (2) Bul. 21: 55

1861 Gomphus exilis Hagen, Synopsis Neur. N. Am. p. 108

1872 Gomphus exilis Hagen, Bost. soc. nat. hist. Proc. 15: 273

1875 Gomphus exilis Hagen, Bost. soc. nat. hist. Proc. 18: 45

1885 Gomphus exilis Hagen, Am. ent. soc. Trans. 12: 263–64 (description of the nymph, and remarks on distribution)

1893 Gomphus exilis Hagen, Am. ent. soc. Trans. 20: 243 (description)

1894 Gomphus exilis Banks, Can. ent. 26: 77 (listed from Ithaca)

1895 Gomphus exilis Calvert, N. Y. ent. soc. Jour. 3: 45 (listed from Keeseville)

1899 Gomphus exilis Kellicott, Odon. Ohio, p. 65 (description and figure)

1900 Gomphus exilis Williamson, Dragon flies Ind. p. 293 (description and figure)

This is one of the most generally distributed, and perhaps the commonest of the gomphines of the northeastern United States. At Saranac Inn it was abundant, flitting by every roadside throughout the month of June and well along into July. The nymphs were found in all waters, and about the first of July the exuviae fairly sprinkled every bank. Few imagos were observed in the immediate vicinity of the water, after leaving it at transformation, and these few were mostly females ovipositing. These spin along through the air at a lively rate, unattended by the male, descending here and there to strike the surface and liberate eggs, making but one or two dips in a place, and flying some distance before descending again. The nymphs transform at the very edge of the water, seldom crawling more than an inch or two above the surface of it. Moss-grown logs in the edges of Little Clear pond were in many

places piled several layers deep with the exuviae of this species, intermixed with a lesser number of G. spicatus skins.

**Nymph.** Total length 26 mm; abdomen 18 mm; hind femur 5.5 mm; width of head 5 mm, of abdomen 6 mm.

Abdomen depressed, lanceolate, regularly narrowed beyond the sixth segment to a rather pointed apex; the 10th segment two thirds as long as the eighth, a little less than half as long as the ninth; lateral spines on segments 6–9, very minute, specially on segment 6, increasing in size posteriorly, on segment 9 one half as long as segment 10: dorsal hooks low and obscure, but pointed on sixth to ninth segments.

Labium with its median lobe a very little convex on the front margin, and sometimes with an imperfect median tooth; lateral lobe considerably arcuate, with a strong end hook, and with 4–7 very variable teeth on its inner margin, each tooth obliquely truncate, with the longer angle directed to the rear.

This species and G. sordidus, offer an easy transition to the Arigomphus group, below.

### Gomphus ventricosus Walsh

1863 Gomphus ventricosus Walsh, Ent. soc. Phil. Proc. 2:249

1875 Gomphus ventricosus Hagen, Bost. soc. nat. hist. Proc. 18:47 (listed)

1900 Gomphus ventricosus Williamson, Dragon flies Ind. p. 287 (description and figure)

This apparently rare species has not yet been taken in New York. I include it in this list because of its occurrence in Illinois and Massachusetts; it will doubtless yet be found within the state. Its nymph is unknown.

### Gomphus amnicola Walsh

1862 Gomphus amnicola Walsh, Acad. nat. sci. Phil. Proc. p. 396

1863 Gomphus amnicola Walsh, Ent. soc. Phil. Proc. 2:256 (note)

1897 Gomphus amnicola Calvert, N. Y. ent. soc. Jour. 5:95 (listed from Bethlehem N. Y.)

1900 Gomphus amnicola Williamson, Dragon flies Ind. p. 294 (description and figure)

Another species which is apparently rare, once collected within the state by Dr Lintner at Bethlehem. The nymph is unknown.

### Gomphus scudderi Selys

1878 Gomphus scudderi Selys, Acad. Belg. (2) Bul. 46:460 ♀

1898 Gomphus scudderi Harvey, Ent. news, 9:62–63 ♂ (description and figures)

This handsome black species (pl. 17, fig. 2), unique in the yellow basal rings on its abdominal segments, has not been reported hitherto

from this state. It was common at Saranac Inn, and even more common, judging by the numbers of exuviae in evidence along the bank, at Axton along Stony brook. But few imagos were seen at large, but many were bred from nymphs taken from Little Clear creek beside the hatchery.

This species, unlike most Odonata, seems to prefer daylight, and even midday as a time for transformation. The boarded banks of the impounded creek beside the hatchery were watched through the entire season, and each day the exuviae left there were gathered. Rarely were any fresh skins found there early in the morning. July was so rainy there was comparatively little time suitable for transformation; and, when the clouds would break away about noon and the sun shine out, I could be sure, on going out, to find some nymphs in transformation. On the few clear days, this was most often observed about noon. All the skins observed were left 3–30 inches above the surface of the water. The nymphs are rather slow and sprawling. The imagos seem to spend little time in flight, preferring to rest on timbers about the rapids of the stream.

**Nymph.** (Pl. 18, fig. 2) Measures in total length 42 mm; abdomen 28 mm; hind femur 5 2 mm; width of head 6.3 mm, of abdomen 8 mm.

Body elongate, depressed, with the long abdomen regularly tapering for half its length; the fringe of hairs on lateral margins very dense and soft; color yellowish brown, darker on the sides of the thorax; eyes black; ocelli yellowish; a double row of trapezoidal blackish spots on the abdomen between the middorsal line and the line of scars each side, each spot with a prolonged external apical angle reaching the apical carina on each segment, the spots on segments 9 and 10 becoming diffused over the sides of the segments; a series of minute, longitudinal yellowish dashes in the apical sutural area of each segment. That so much of color pattern is observable is doubtless due to the fact that these nymphs live in comparatively clean sand.

Abdomen depressed, and with a well marked middorsal impressed line, and no dorsal hooks, save the merest rudiment on the apex of the ninth segment; lateral spines well developed on segments 6–9 (there are tufts of hairs on the latter apical angles of segments before the sixth) increasing a little in size posteriorly, those of the ninth segment closely appressed, and hardly surpassing the base of the tenth segment.

Mentum of labium a third longer than wide; front border of median lobe nearly straight, with a sparse fringe of flattened scale like hairs; lateral lobe strongly incurved at about a right angle beyond the base of the movable hook; about four teeth on the inner margin, increasing a little in size posteriorly.

While nymphs of several sizes were taken together in the creek, they seemed to have a definite period, including hardly more than the month of July, for transforming.

Aug. 2 was the date of the first imago captured at large. June 30 was the date of the first imago bred.

## Gomphus vastus Walsh

1862 Gomphus vastus Walsh, Acad. nat. sci. Phil. Proc. p. 391

1875 Gomphus vastus Hagen, Bost. soc. nat. hist. Proc. 18 : 47 (listed from New York)

1872 Gomphus vastus Cabot, Mus. compar. zool. Mem. v. 3, pl. 2, fig. 4 (description and figure of nymph)

1885 Gomphus vastus Hagen, Am. ent. soc. Trans. 12 ; 265–66 (description of nymph)

1890 Aeshna vasta Kirby, Cat. Neur. Odon. p. 66 (listed)

1892 Gomphus vastus Banks, Am. ent. soc. Trans. 19 : 352 (listed)

1893 Gomphus vastus Calvert, Am. ent. soc. Trans. 20 : 245 (description)

1895 Gomphus vastus Calvert, N. Y. ent. soc. Jour. 3 : 45 (listed from New York)

1899 Gomphus vastus Kellicott, Odon. Ohio, p. 57–58 (description and figure)

1900 Gomphus vastus Williamson, Dragon flies Ind. p. 287 (description and figure)

This striking species frequents the shores of the Great lakes and the larger streams. The nymphs live on the bottom at some depth. In the above bibliography are indicated numerous descriptions and some figures of both nymph and adult. The species may be recognized by the characters stated in the tables.

## Gomphus plagiatus Selys

1854 Gomphus plagiatus Selys, Acad. Belg. (2) Bul. 21 : 57

1861 Gomphus plagiatus Hagen, Synopsis Neur. N. Am. p. 109

1885 Gomphus plagiatus Hagen, Am. ent. soc. Trans. 12 : 269–70 (description of the nymph)

1893 Gomphus plagiatus Calvert, Am. ent. soc. Trans. 20 ; 244 (description)

1897 Gomphus plagiatus Calvert, N. Y. ent. soc. Jour. 5 : 95 (listed from New York)

1899 Gomphus plagiatus Kellicott, Odon. Ohio, p. 69–70 (description and discussion)

1900 Gomphus plagiatus Williamson, Dragon flies Ind. p. 295–96 (description and figure)

A very large species, apparently commonest about broad marshy tracts, taken but once as yet in this state. It will be easily recognized by the characters stated in the tables.

## Gomphus spiniceps Walsh

1862 ?Macrogomphus spiniceps Walsh, Acad. nat. sci. Phil. Proc. p. 389

1854 Gomphus spiniceps Selys, Acad. Belg. (2) Bul. 21 : 57

1885 Gomphus spiniceps Hagen, Am. ent. soc. Trans. 12:270–71 (description of nymph)

1899 Gomphus spiniceps Kellicott, Odon. Ohio, p. 69 (description and figure)

1900 Gomphus spiniceps Williamson, Dragon flies Ind. p. 295 (description and figure)

A strong flying species, frequenting rapid streams. Transforms in midsummer, and appears in flight and ovipositing late in the summer or early in autumn. "Observed flying late in the afternoon, and ovipositing in a small brook that was rippling over pebbles." Kellicott (*loc. cit.*) The species has not been recorded from this state hitherto, but there are New York specimens in the Museum of comparative zoology, and the species has long been known from Illinois and Massachusetts.

## **Gomphus spicatus** Hagen

1854 Gomphus spicatus Hagen, Acad. Belg. (2) Bul. 21:51

1861 Gomphus spicatus Hagen, Synopsis Neur. N. Am. p. 107

1875 Gomphus spicatus Hagen, Bost. soc. nat. hist. Proc. 18:47 (listed; distribution given)

1890 Aeshna spicata Kirby, Cat. Neur. Odon. p. 64 (listed: bibliography)

1892 Gomphus spicatus Banks, Am. ent. soc. Trans. 19:353 (listed)

1895 Gomphus spicatus Calvert, N. Y. ent. soc. Jour. 3:45 (listed)

1897 Gomphus spicatus Van Duzee, N. Y. ent. soc. Jour. 5:89 (listed from Clarence)

1897 Gomphus spicatus Calvert, N. Y. ent. soc. Jour. 5:93 (listed from Clarence)

1899 Gomphus spicatus Kellicott, Odon. Ohio, p. 97–98 (description and figure)

1900 Gomphus spicatus Williamson, Dragon flies Ind. p. 292 (description and figure)

This is a common species in the northeastern United States, ranging from Illinois eastward; it is more generally distributed throughout its range than are most gomphines. Next to G. exilis it was the commonest Gomphus at Saranac Inn, where it frequented all sorts of waters. Imagos were common during the latter part of June and the first two weeks of July along the wagon road and railroad between Little Clear and Big Clear creeks; they were foraging there, and, while a little shy and wary, were not very difficult to catch with a net.

**Nymph.** Total length 31 mm; abdomen 20 mm; hind femur 6.2 mm; width of head 5 mm, of abdomen 7 mm.

Body elongate, somewhat depressed; abdomen lanceolate, pointed.

Color dark brownish, with some black marks on the sides of the thorax; margins of the abdominal segments darker; a pair of black dots on the dorsum of each of the middle abdominal segments.

Dorsal hooks of abdomen represented only by minute backward prolongations of the median ridge on all the segments; lateral spines on segments 7–9, increasing in size posteriorly, small, on the ninth segment much shorter than the 10th segment, against which they are closely appressed; 10th segment two thirds as long as the eighth, and a little less than half as long as the ninth.

Labium with its median lobe distinctly convex anteriorly, and with a brown tooth in the middle in the midst of the usual flat, fringing hairs; lateral lobe regularly arcuate, with about nine coarse, trapezoidal, serrately recurved teeth on its inner margin.

A goodly number of specimens of the nymphs were collected from Little Clear creek on the hatchery grounds, Little Clear pond near its outlet, and from Bone pond.

## Gomphus villosipes Selys

1854 Gomphus villosipes Selys, Acad. Belg. (2) Bul. 21:53

1861 Gomphus villosipes Hagen, Synopsis Neur. N. Am. p. 105

1890 Aeshna villosipes Kirby, Cat. Neur. Odon. p. 64 (bibliography)

1893 Gomphus villosipes Calvert, Am. ent. soc. Trans. 20:244–45 (description)

1894 Gomphus villosipes Banks, Can. ent. 26:77 (listed from Ithaca)

1895 Gomphus villosipes Calvert, N. Y. ent. soc. Jour. 3:45 (listed from Ithaca)

1897 Gomphus villosipes Van Duzee, N. Y. ent. soc. Jour. 5:89 (listed from Grand Island)

1897 Gomphus villosipes Calvert, N. Y. ent. soc. Jour. 5:93 (listed from Grand Island)

1897 Gomphus villosipes Needham, Can. ent. 29:166 (note on rearing the nymph at Ithaca)

1899 Gomphus villosipes Kellicott, Odon. Ohio, p. 63 (description and figure)

1900 Gomphus villosipes Williamson, Dragon flies Ind. p. 291

This is an exceedingly common species at Ithaca, where I have picked up thousands of the exuviae at a time along the borders of the Cascade pond in June. The imagos fly about or rest on the snags and projecting rocks, which are common in the turbulent creeks about Ithaca. The nymphs burrow in the bottom in shallow water, seeming to prefer banks of somewhat clayey mud. They are slow moving, stiffly sprawling creatures, powerful, rapacious, and seemingly the dominant animals in the bottom mire.

**Nymph.** Total length 35 mm; abdomen 23 mm; hind femur 7.5 mm; width of head 6 mm, of abdomen 8.5 mm.

Body depressed, with legs wide apart and very sprawling; abdomen lanceolate, pointed, rapidly narrowed beyond the fifth to the base of the ninth segment, more slowly narrowed thereafter. The whole body and all appendages, clothed with a dense scurfy pubescence, which is conspicuously marked with bare lines or "scars."

Abdomen with obtuse, continuous middorsal ridge, showing no trace of dorsal hooks; lateral spines very small, closely appressed, and inconspicuous, present only on segments 8 and 9, on 8 very short, on 9 longer, but closely applied to the sides of segment 10. The 10th segment is hardly shorter than the eighth, but it is less than half as long as the ninth.

The mentum of the labium is distinctly produced and rounded on its front border, with a median brown tooth in the midst of the fringing flat hairs. The lateral lobe is broad and strongly arched, with about six coarsely serrate teeth on its inner margin.

### Gomphus furcifer Hagen

1878 Gomphus furcifer Hagen, Acad. Belg. (2) Bul. 46:458

1899 Gomphus furcifer Kellicott, Odon. Ohio, p. 64 (description and figure)

1900 Gomphus furcifer Williamson, Dragon flies Ind. p. 292 (description and figure)

This species has not hitherto been recorded from New York state, and I have not seen it there at large; but there is a specimen bearing an Ithaca label in the Cornell university collection. The nymph is unknown.

## DROMOGOMPHUS

A single species of this genus belongs to the New York fauna.

### Dromogomphus spinosus Selys

1854 Gomphus spinosus Selys, Acad. Belg. (2) Bul. 21:59

1861 Gomphus spinosus Hagen, Synopsis Neur. N. Am. p. 102

1862 Gomphus spinosus Walsh, Acad. nat. sci. Phil. Proc. p. 391 (note)

1863 Gomphus spinosus Hagen, Stett. ent. zeit. 24:373

1873 Gomphus spinosus Hagen, Bost. soc. nat. hist. Proc. 16:359

1875 Gomphus spinosus Hagen, Bost. soc. nat. hist. Proc. 18:44 (bibliography)

1893 Dromogomphus spinosus Calvert, Am. ent. soc. Trans. 20:245 (description)

1894 Dromogomphus spinosus Banks, Can. ent. 26:77 (listed from Ithaca and Baldwinsville)

1895 Dromogomphus spinosus Calvert, N. Y. ent. soc. Jour. 3:45 (listed from Ithaca and Baldwinsville)

1897 Dromogomphus spinosus Calvert, N. Y. ent. soc. Jour. 5:93 (listed from Karner)

1897 Dromogomphus spinosus Needham, Can. ent. 29:186 (characters of the nymph)

1899 Dromogomphus spinosus Kellicott, Odon. Ohio, p. 71 (description)

1900 Dromogomphus spinosus Williamson, Dragon flies Ind. p. 296 (description)

This species has been taken sparingly and in a few places within the state, but it is probable that it frequents the borders of most of the larger

bodies of water. Prof. Herrick of the Agricultural college of Mississippi found it transforming abundantly on the shore of Canandaigua lake at the natural science camp in June 1897. I have found it at Ithaca and at Saranac Inn; at the latter place only in Little Clear pond, near the outlet. That was during the week which included June 30. The nymphs were crawling up out of rather deep water on stumps and logs on the bank to transform.

A big pine stump that stood partly in the water, halfway between the outlet and the cold water pipe, seemed a favorite place of transformation. It was fairly dotted over with exuviae, most of which were several feet above the water. No imagos were seen, excepting the few that were bred.

**Nymph.** (Pl. 18, fig. 1) Total length 33 mm; abdomen 22 mm hind femur 7 mm; width of head 6 mm, of abdomen 7 mm.

Body elongate, little depressed, little hairy; color dirty brownish, becoming clear brown on the apex of the abdomen; some darker markings on the sides of the thorax and at the lateral margins of the abdomen, and across the base of the dorsum of the middle abdominal segments.

Head cordate in outline, the hind margin being broadly emarginate; antennae long, considerably surpassing the tip of the labrum, and upturned beyond the end of it; first segment twice as large as the second, both globular; third segment narrowly cylindric, more than twice as long as the two basal ones together, bearing the minute, rudimentary, globular, fourth segment on its upturned tip; burrowing hooks well developed.

Abdomen narrowed beyond the sixth segment rather regularly; dorsal hook on segments 2–9 regularly increasing in size and sharpness, and regularly increasingly declined posteriorly, that on segment 9 being a direct continuation of the sharp middorsal ridge of the segment, black tipped, lateral spines on segments 6–9 increasing in size posteriorly, those of the ninth segment reaching the level of the middle of the 10th segment; the eighth segment is a third longer than the 10th; the ninth segment is two and one half times as long as the 10th; the superior and inferior appendages are somewhat longer than the 10th segment, but the laterals are about equal to it, being about one fourth shorter than the other appendages.

The mentum of the labium is rather regularly widened anteriorly, with a straight front border; lateral lobes strongly arcuate, with end hook distinctly more prominent than the nine or ten coarse, angulately serrate teeth before it on the inner margin.

## Subfamily AESCHNINAE

This group includes the largest, fleetest, and most voracious of our dragon flies. Many of them are common and very well known. Most of the species are marked with bright blues and greens. They roam far from water, and often find their way into houses in warm weather. Several species are commonly seen coursing over lawns in the evening twilight.

The nymphs are known for a larger proportion of the genera than in any other subfamily. They are climbers among green plants, over timbers, on swaying roots, etc., preferring the border of open water or the edge of a current. They are slender, active, clean, with smooth bodies marked with a color pattern of greens and browns, well adapted to concealment in the midst of their natural environment. They will eat almost any living animal that they can capture and hold, and they eat one another with evident relish.

The nymphs agree in the possession of the following characters: Head depressed; antennae (when grown) six to seven-jointed, filiform; eyes large, very prominent, covering the anterolateral angles of the head; labium very long, reaching between the bases of the middle legs, mentum flat, not covering the face, median lobe with a minute median cleft, lateral lobe denticulate on inner side, and with a terminal hook, as well as the usual movable hook; legs slender, fitted for climbing and clinging; tarsi three-jointed; prothorax with a transverse, dorsal, flattened area, and a pair of conic processes above each coxa; spiracles large, conspicuous; abdomen somewhat spindle-shaped, with lateral margins becoming acute posteriorly; lateral spines present on a variable number of the segments; inferior abdominal appendages at least twice as long as the lateral appendages.

The following tables will enable any one to distinguish the members of our few genera.

KEY TO GENERA

*Imagos*

*a* The radial sector (Rs., fig. 9) simple

*b* But two cubito-anal cross veins; vein $M_2$ undulate; supratriangle without cross veins; but one cross vein under the stigma.. Gomphaeschna

*bb* With three or more cubito-anal cross veins; vein $M_2$ not undulate; supratriangle divided by cross veins; several cross veins under the stigma

*c* Basal space traversed by cross veins.......................... Boyeria

*cc* Basal space open ........................................ Basiaeschna

*aa* Radial sector bearing an apical fork

*b* Sectors of the arculus (veins $M_{1-3}$ and $M_4$) separating from the arculus at or below its middle

*c* The radial sector symmetrically forked, between it and the supplementary vein below it, one or two rows of cells

*d* Face strongly produced above, the upper margin of the frons very acute; the veins $M_1$ and $M_2$ parallel to the level of the stigma; radial sector and the supplementary vein below it separated by a single row of cells Nasiaeschna

*dd* Face vertical, not sharply angulate at upper edge of frons; veins $M_1$ and $M_2$ approximated at the stigma; the radial sector and the supplementary vein below it separated by two rows of cells Epiaeschna

*cc* The radial sector strongly deflected toward the stigma at the base of its fork, unsymmetric; between it and the supplementary vein below it, three to seven rows of cells ........................................ Aeschna

*bb* Sectors of the arculus springing from above the middle of the arculus. Anax

### *Nymphs*

These are known for all the foregoing genera except Gomphaeschna: the nymphs figured and described by Cabot and referred by supposition to that genus, were the males of Boyeria (see below under the account of that genus). Among all our nymphs that are still unknown, that of Gomphaeschna remains one of the most desirable discoveries yet to be made.

*a* Hind angles of the head viewed from above, sharply angulate
  *b* Lateral lobe of labium squarely truncate on apex ............... Boyeria
  *bb* Lateral lobe of labium with taper-pointed apex ............ Basiaeschna
*aa* Hind angles of the head obtusely rounded
  *b* With lateral spines on abdominal segments 4–, 5–, or 6–9.
    *c* With lateral spines on segments 4–, or 5–9
      *d* With dorsal hooks on abdominal segments 7–9 ......... Nasiaeschna
      *dd* With no dorsal hooks on abdomen ........................ Epiaeschna
    *cc* With lateral spines on abdominal segments 6–9 .................. Aeschna
  *bb* With lateral spines on abdominal segments 7–9 ........................ Anax

So well marked are these genera that their nymphs may be recognized by the following

### *Single distinctive characters*

Nasiaeschna alone has dorsal hooks on the abdomen.
Basiaeschna alone has the apices of its lateral labial lobes pointed.
Anax alone has lateral spines on abdominal segments 7–9 only.
Aeschna alone has lateral spines on abdominal segments 6–9 only.
Boyeria alone has two teeth on the front border of the median lobe of the labium, at a distance either side from the median cleft.
Epiaeschna alone is lacking in all the above characters.

## GOMPHAESCHNA

The single regional species G. furcillata Say has not been taken as yet within this state, so far as records show. Its nymph is unknown, that one referred to this species by Cabot on supposition proving to be the male nymph of Boyeria, described below.

## BOYERIA

This genus includes the single North American species.

### Boyeria vinosa *Say*

1839 Aeschna vinosa Say, Acad. nat. sci. Phil. Jour. 8:13
1839 Aeschna 4-guttata Burmeister, Handb. ent. 2:837
1861 Aeschna 4-guttata Hagen, Synopsis Neur. N. Am. p. 130
1875 Neuraeschna vinosa Hagen, Bost. soc. nat. hist. Proc. 18:37 (full bibliography and distribution)

1892 Aeschna vinosa Banks, Am. ent. soc. Trans. 19:353 (listed from New York)

1893 Fonscolombia vinosa Calvert, Am. ent. soc. Trans. 20:247 (description)

1895-97 Fonscolombia vinosa Calvert, N. Y. ent. soc. Jour. 3:45 and 5:93 (listed from Keeseville, Ithaca, Schoharie, Piseco lake, Elk lake, Colden, and Westchester co.)

1899 Fonscolombia vinosa Kellicott, Odon. Ohio, p. 90 (description)

1900 Boyeria vinosa Williamson, Dragon flies Ind. p. 300-1 (description)

1881 Neuraeschna vinosa Cabot, (Nymph) Mus. compar. zool. Mem. 8:29, 39, pl. 2, fig. 3

This interesting species, which seems likely to be found inhabiting almost every woodland creek in the state, was very common at Saranac Inn in Little Clear creek, and in the borders of the pond above. The nymphs were transforming commonly on the sides of timbers in the edge of the water from the beginning of our session till the latter end of July. A number of both sexes were reared in our cages. A few imagos might be seen, specially afternoons in favorable weather from midsummer till the end of our session, about the creek on the hatchery grounds. They glide along above the stream, not very rapidly, on well poised, transparent wings, which against the background of the water are well nigh invisible. The two big round yellow spots on each side of the thorax distinguish this species from all its kin, even while in flight.

The nymphs, which are generally quite dark colored, seem to prefer timbers, trailing roots, driftwood, etc., as a foraging ground. I have rarely taken them from green vegetation.

**Nymph.** Total length ♂ 33, ♀ 36 mm; abdomen, ♂ 22.5, ♀ 25 mm; hind femur 5.5 mm; width of head 7 mm, of abdomen 7.5 mm.

Body elongate, slender, smooth; color blackish brown, obscurely marked with paler in transverse rings on the legs, and in dashes, tending to become arranged in interrupted, longitudinal rows on the abdomen.

Head concave behind, with truncated hind angles; sides straight, diverging strongly anteriorly to meet the very prominent eyes; labium moderate; middle third of front margin of median lobe straight, with a tooth at each side remote from the median cleft.

Abdomen widest across the fifth and sixth segments, tapering unequally to the ends; no dorsal hooks; lateral spines on segments 5–9, on 5 small, on 6–9 conspicuous, increasing a little in size posteriorly, those of the ninth segment three fourths as long as the 10th segment; the abdominal segments are longest in the middle, and decrease a little toward both ends; the appendages are longer than the last two segments together, and differ in the two sexes in the form of the apex of the superior appendage; in the ♂ this has a distinct narrow apical cleft, in the ♀ the cleft is closed when grown; in small female nymphs, however, I have seen it quite as widely open and as distinct as in the male: in both sexes

the laterals are one fourth as long, and the superiors eight ninths as long as the inferiors.

Some smaller nymphs from the creek show a middorsal black band on the abdomen, divided by a median row of small yellow spots, largest on the eighth segment.

### Basiaeschna janata Say

1839 Aeschna janata Say, Acad. nat. sci. Phil. Jour. 8:13

1842 Aeschna minor Rambur, Ins. Neur. p. 207

1861 Aeschna janata Hagen, Synopsis Neur. N. Am. p. 125

1875 Aeschna janata Hagen, Bost. soc. nat. hist. Proc. 18:33 (full bibliography and distribution)

1895 Basiaeschna janata Calvert, N. Y. ent. soc. Jour. 3: 45 (listed from Keeseville)

1899 Basiaeschna janata Kellicott, Odon. Ohio, p. 81 (description)

1900 Basiaeschna janata Williamson, Dragon flies Ind. p. 301 (description)

This species is perhaps the earliest of the Aeschninae. It was common about the hatchery grounds on our arrival, and had about disappeared by midsummer. I got mostly immature nymphs at Saranac Inn, but I bred the species abundantly at Ithaca several years ago. I saw females ovipositing several times during the first week of our stay at Saranac Inn, and watched the process once in detail. In each instance observed the eggs were deposited in leaves of a species of burreed, Sparganium, which, where it grew in the deeper water of the creek, trailed its long leaves on the surface of the stream. The female flitted from plant to plant, making a few thrusts with her ovipositor into each at the water line, and then settled and balanced herself carefully on a long, floating leaf; this was doubtless a most favorable place for the eggs, and she settled down to more extensive operations. Backing down into the water till the abdomen was wholly submerged, she began thrusting with her ovipositor, first to right and then to left, moving forward a little between thrusts, leaving behind a double row of egg punctures, as regular as the neatest double stitching that might be done with a needle. Several such double rows of eggs were placed in the tissues of this leaf before she left it. The leaf was found to be thickly covered on the under side (as all submerged surfaces were covered in the creek at that time) with hundreds of red hydras, in all stages of budding. I placed the leaf in a hatchery trough, where the hydras remained in good condition till after the hatching of the eggs.

**Nymph.** Total length 43 mm; abdomen 30 mm; hind femur 6 mm; width of head 7.5 mm; of abdomen 8 mm.

Body elongate, slender, nearly smooth; color brownish black, with paler rings on the femora and tibiae, three or four rings on each; pale

marks on the lateral margins of the abdominal segments at base; a broad middorsal pale band on abdomen, mottled with brown, and including two blackish spots on the eighth segment; appendages, spines, tarsal segments and claws, yellow, blacktipped.

Head with very prominent, anteriorly directed eyes, narrowed behind the eyes to very sharp hind angles; between these angles the rear of the head is slightly concave; the labium has its median lobe prominent, fringed, distinctly cleft; the lateral lobe, rather small, tapering to its incurved apex, rather regularly.

Abdomen without dorsal hooks, with lateral spines on segments 3 or 4–9, increasing in size posteriorly, those of the ninth segment about equaling in length the 10th segment; inferior appendages long and very sharp, distinctly longer than the last two abdominal segments; superior one half to three fifths as long as the inferiors, its apex with a round notch; laterals about half as long as the superior.

The unusual brevity of the superior appendage is about as distinctive as the shape of the lateral labial lobe, indicated in the above table.

### NASIAESCHNA[1]

There is a single species.

### Nasiaeschna pentacantha Rambur

1842 Aeschna pentacantha Rambur, Ins. Neur. p. 208

1861 Aeschna pentacantha Hagen, Synopsis Neur. N. Am. p. 129 (description)

1862 Aeschna pentacantha Walsh, Acad. nat. sci. Phil. p. 397 (notes)

1875 Aeschna pentacantha Hagen, Bost. soc. nat. hist. Proc. 18:37 (bibliography and distribution)

1888 Epiaeschna heros (nymph) Garman, Ill. state lab. nat. hist. Bul. 3:178 (descriptive notes)

1895 Aeschna pentacantha Banks, Ent. news, 6:124 (recorded from Baldwinsville)

1897 Aeschna pentacantha Calvert, N. Y. ent. soc. Jour. 5:95 (recorded from Baldwinsville)

1900 Aeschna pentacantha Williamson, Dragon flies Ind. p. 305 (description)

This species ranges from Massachusetts to Texas, and from Illinois to Georgia: it is apparently rare throughout its range. Probably not more than a dozen specimens of the adult insect exist in collections.

As to the nymph, Garman first found it in the Mississippi bottoms near Quincy Ill. His types were lent me for study several years ago by Prof. Forbes. I was able to refer them by exclusion to this species. Mr Hart of the Illinois state laboratory, has since written me that he has successfully reared similar nymphs obtained by him in a creek near Champaign Ill. Thus their identity is settled. I have since obtained well

1 de Selys 1900: diagnosis in French, included in a paper "Odonaten aus Neu-Guinea" by F. Förster, in *Termeszetrajzi Füzetek*, v. 23 (Budapest).

grown nymphs from Moline Ill. Two imagos taken by Prof. R. H. Pettit at Baldwinsville, Onondaga co., constitute the only record of the species for this state.

**Nymph.** (The largest I have before me, not grown, as shown by the shortness of the wing cases.) Measures 24 mm; abdomen 16 mm; hind femur 4 mm; width of head 5.5 mm, of abdomen 6 mm.

Color blackish, labium and tarsi yellowish; body rough granulate, but not hairy, with paired tubercles obtuse above the base of the antennae, and on the middle of the vertex, and on the middle of the superolateral ridge that extends from the rear of the eyes to the hind angles of the head; a pair also on the superolateral angles of the prothorax; and the usual two pairs above the bases of the coxae, the anterior a little longer and stouter, but both directed anteriorly; three or four pairs above the middle and hind coxae, running down into a ridge which extends on these coxae; a dorsal, tuberculate, superior ridge on all the femora; dorsal hooks represented on all the segments of the abdomen, becoming prominent and pointed on segments 6–9; lateral spines on segments 5–9, increasing in length posteriorly, those of the ninth segment, two thirds as long as the 10th segment; appendages more than twice as long as the 10th segment, superior and inferiors of equal length, laterals one fourth to one fifth as long as the others, superior, obtuse at tip, inferiors finely denticulate exteriorly.

Head considerably narrowed behind the eyes, and with a deep, quadrangular excavation of the hind margin; eyes with a very long anterior border, and a long pointed hind angle lying on the vertex; labium with the cleft of the median lobe somewhat v-shaped, not closed; lateral lobe truncate on apex, with about 18 denticles on inner margin.

### EPIAESCHNA

There is a single North American species.

## Epiaeschna heros Fabricius

1798 Aeshna heros Fabricius, Ent. syst. Suppl. p. 285

1839 Aeshna multicincta Say, Acad. nat. sci. Phil. Jour. 8:9

1861 Aeschna heros Hagen, Synopsis Neur. N. Am. p. 128

1869 Aeschna heros Harris, Ent. correspondence. p. 326 (notes)

1862 Aeschna heros Walsh, Acad. nat. sci. Phil. Proc. p. 397 (notes)

1875 Aeschna heros Hagen, Bost. soc. nat. hist. Proc. 18:36 (bibliography and distribution)

1881 Epiaeschna heros (nymph) Cabot, Mus. comp. zool., Mem. 8:30, 39, pl. 1, fig. 3

1893 Epiaeschna heros Calvert, Am. ent. soc. Trans. 20:246–47 (description)

1895–97 Epiaeschna heros Calvert, N. Y. ent. soc. Jour. 345; 5:93 (listed from Dobbs Ferry, New York, Ithaca, Albany and Buffalo)

1899 Epiaeschna heros Kellicott, Odon. Ohio, p. 81 (description)

1900 Epiaeschna heros Williamson, Dragon flies Ind. p. 302 (description)

This, our largest dragon fly, is widely distributed throughout the state, and, for that matter, throughout the whole eastern United States. Its

strikingly large size, and its habit of flying into houses not unfrequently, and its apparent migrations in numbers, have made it a rather well known species.

Since the nymph has been described and figured by Cabot, it will suffice here to give a brief statement of its more distinctive characters.

**Nymph.** Apparently full grown, measures in total length 46 mm; abdomen 32 mm; hind femur 7.5 mm; width of head 10 mm, of abdomen 10 mm.

Body very elongate, widest across the eyes and the seventh and eighth abdominal segments. Head flat, much narrowed behind the eyes, with a deep, well rounded concavity on the hind margin, and obtuse hind angles; labium long extending posteriorly between the bases of the middle legs; mentum (fig. 13) with sides parallel for half its length, then suddenly widened in a regular curve to the bases of the lateral lobes; median lobe with convex front border divided by a shallow open cleft, bearing a fringe of short scales on either side of the cleft; lateral lobe truncate on tip with a short hook on inner angle at tip, before which are some 12 to 15 denticles.

Fig. 13 Labium of Epiaeschna heros Fabr., from within. Photo by J. G. Needham

Abdomen with an obtuse middorsal ridge; lateral spines on segments 5–9, increasing in size posteriorly, on 9 hardly longer than half of the length of the 10th segment, but broadly triangular; superior appendage almost as long as the inferiors, not cleft at apex; laterals half as long, inferiors not quite as long as segments 9 and 10 together.

### AESCHNA

Three closely related species of this genus are known from the state. Male imagos of these species may be separated by the following key.

#### KEY TO SPECIES OF AESCHNA

*a* Anal triangle of hind wing of male consisting usually of three cells. Superior abdominal appendages of male with a prominent inferior spine at the distal end; genital valve of female strongly elevated at the apex .. constricta

*aa* Anal triangle of the hind wing of the male consisting generally of two cells; superior appendage of the male without prominent inferior spine; genital valve of female not strongly elevated at its apex

*b* Superior abdominal appendages of the male with a superior longitudinal carina denticulated .......... clepsydra

*bb* Superior appendages of the male with the superior longitudinal carina not denticulated .......... verticalis

I am not able to distinguish between the nymphs of these species. Constricta and clepsydra were both common at Saranac Inn during the latter half of the summer. I collected many nymphs, and it would seem likely that I should have both species; but I have found hitherto no specific differences between them. The imagos of the three species are similar in habits and are often found flying together. It is probable that the nymphs are likewise similar in habits. The nymph of Aeschna constricta is described and figured by Cabot[1]. Descriptions of these three species will be found in the monographs of Calvert, Kellicott and Williamson, frequently cited in the preceding bibliographies of species. Under these circumstances it seems unnecessary to enter into a detailed discussion of them. It will suffice, for the certain recognition of nymphs of the genus, to restate the chief characters of the nymph of A. constricta, a species which I have bred abundantly at Ithaca and at Saranac Inn.

**Nymph.** Fully grown measures in total length 43 mm, abdomen 31 mm, hind femur 6.5 mm; width of head 7.5 mm, of abdomen 7.5 mm.

Body elongate, graceful, active; color varied green and brown, the amount of either color varying to agree with environment, the paler markings of the dorsum generally tending to form longitudinal interrupted streaks.

Head with prominent, well-rounded eyes, whose hind angles almost meet on the vertex; rear of head hardly convex posteriorly; hind angles broadly rounded; labium moderately widened in distal half of mentum; middle lobe with closed median cleft; lateral lobe squarely truncate on end, denticulate within.

Abdomen widest in the middle, where the segments are also longest; lateral spines on segments 6–9, on 6 minute, on 9 a little longer than half the length of the 10th segment; inferior appendages longer than segments 9 and 10; the deeply notched superior appendage three fourths as long as the inferiors, the laterals one half as long as the inferiors and with very sharp, incurvate points.

## ANAX

The single species discussed below properly belongs to our fauna: another tropical species, Anax longipes is occasionally picked up on our Atlantic coast.

1773 Libellula junia Drury, Illus. exotic ent. v. 1, pl. 47, fig. 5n

1842 Aeschna spiniferus Rambur, Ins. Neur. p. 186, pl. 1, fig. 14

1854 —— —— Emmons, Agric. N. Y. v. 5, pl. 15, fig. 3 (colored figure of the male; no description; no name)

1861 Anax junius Hagen, Synopsis Neur. N. Am. p. 118

1875 Anax junius Hagen, Bost. soc. nat. hist. Proc. 18:32 (full bibliography and distribution)

[1] Immature state of the Odonata. 1881. pt 2.

1890 Anax junius Hagen, Psyche, 5 : 305 (critical account of the species)
1893 Anax junius Calvert, Am. ent. soc. Trans. 20 : 249 (description)
1897 Anax junius Calvert, N. Y. ent. soc. Jour. 3 : 46 and 5 : 93 (listed from New York, Ithaca, Schoharie and Buffalo)
1899 Anax junius Kellicott, Odon. Ohio, p. 77
1900 Anax junius Williamson, Dragon flies Ind. p. 306
1881 Anax junius Cabot, (nymph) Mus. comp. zool. Mem. 8 : 15, 36, pl. 1, fig. 2

## Anax junius Drury

This well known species, which is very common in most parts of the state, was rather rare at Saranac Inn. A single nymph was taken from the little bog pond on the inn wagon road, and a single male imago was observed flying over the same pond. Elsewhere the imagos are on the wing from March till November; they fly from daylight to dark, and are fleet, powerful and fearless.

The female in ovipositing is often held by the male, specially in early spring, often is unattended, and sometimes descends bodily into the water. In early spring the eggs are inserted in the water-soaked stems of reeds, in floating sticks, etc.; later in the season they are placed in the tissues of green and growing aquatic plants.

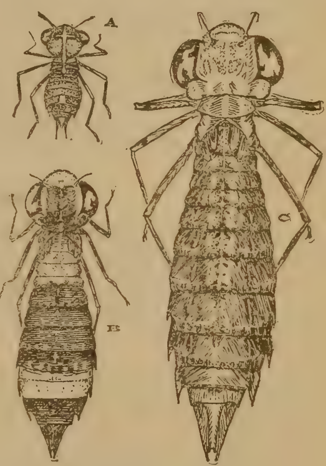

Fig. 14 Early stages of nymph of Anax junius Dru., showing changes of color pattern A, newly hatched: B, one fourth grown; C, one half grown

The nymph of this species is probably better known than that of any other. It is sure to get into the net of the aquatic collector. It clings to water weeds nearer the surface, usually, than the bottom, in an attitude of alertness, with head poised low and abdomen slightly elevated. Locomotion is relatively rapid, either by walking, or by swimming by ejections of water from the respiratory chamber. It is a notoriously cannibalistic species: among abundant and choice food, the larger nymphs will eat the smaller ones, and two of equal size can not be safely kept together in close quarters.

Cabot[1] has figured and described the nymph, and many indifferent reproductions of his figure are current. The following brief diagnostic statement of its principal characters will serve for its recognition.

**Nymph.** (fig. 14) Measures in total length 39 mm; abdomen 29 mm; hind femur 8 mm; width of head 8 mm, of abdomen 8.4 mm.

[1] Immature state of the Odonata. 1881. pt 2.

Body slender, smooth; colors brown and green, in a pattern of longitudinal streaks, well adapted to concealment among plant stems, the depth of the color varying to suit the environment.

Head strongly depressed, with the eyes covering the greater part of the sides of it; labium very long, reaching posteriorly the base of the hind legs; the mentum regularly widened from base to apex, produced median lobe with a closed median cleft; lateral lobe suddenly rounded off at end to the incurved internal end hook, but hardly truncate; legs long and slender as befits its climbing habits, tibiae and femora faintly ringed with brown; abdomen with strong and evident lateral spines on segments 7-9 only; superior abdominal appendage with a well rounded apical notch, its length about seven eighths that of the inferiors, which are longer than segments 9 and 10 together; lateral appendages two fifths as long as the inferiors; spines of the ninth segment about as long as the 10th segment.

## Subfamily PETALURINAE

There is but one genus and species occurring in the eastern United States: both will be recognized by the characters given in the table for major groups.

### Tachopteryx thoreyi Selys

1857 Uropetala thoreyi Selys, Monographie des gomphines, p. 373 (♂)

1861 Petalura thoreyi Hagen, Synopsis Neur. N. Am. p. 117

1878 Tachopteryx thoreyi Selys, Acad. Belg. (2) Bul. 46: 696 (♀)

1893 Tachopteryx thoreyi Calvert, Am. ent. soc. Trans. 20: 241 (description)

1900 Tachopteryx thoreyi Williamson, Ent. news, 11: 398-99 (habits)

1900 Tachopteryx thoreyi Williamson, Dragon flies Ind. p. 281 (description)

This species, originally described from a single male specimen taken in the vicinity of New York, has apparently not been found in the state since that time. It is now known to be distributed from Massachusetts to Florida and Texas. According to Mr Williamson, who has published the little that is known concerning its habits, it flies in Pennsylvania during the whole of June and the first half of July. It is "usually observed resting in sunny situations on fences or trees, at the edges of woodland . . . stream and small marshy area near . . . Easily approached . . . once aroused, its flight is swift and strong."

On June 4, 1900 D. A. Atkinson took in transformation a single female nymph of this species near Pittsburg Pa. E. B. Williamson described and figured this nymph in *Entomological news.* 1901. 12: 1–3, pl 1, and then very kindly loaned me the specimen for study. From this specimen I have drawn the labium and antenna shown in figure 15 and the brief statement of characters given herewith.

**Nymph.** Length 38 mm.

Antennae 7-jointed, depressed, hairy on lateral margins, the segments short and broad.

Labium short and stout, median lobe with a narrow median cleft and denticulate margin; lateral lobes truncate on end, scarcely denticulate: no raptorial setae.

Legs stout, with prominent, twisted, hair-fringed, longitudinal carinae; tarsi 3-3-3 jointed.

Wing cases laid parallel along the back, their apices reaching the middle of the fifth segment.

Abdomen tapering beyond the fifth segment with thin flaring lateral margins showing on each of segments 4–9 an angle at the middle and a flat tooth at the apex, and with a dorsal row of hairy tubercles on segments 5–9, parallel to the lateral margin but nearer the median line: appendages obtuse, the superior with a broad, shallow, apical emargination.

The eggs are deposited in wet, boggy places, when there is hardly any water standing, and the nymph lives in the mud in such places.

### Subfamily CORDULEGASTERINAE

A small group of large species, inhabiting mainly clear streams that flow through upland marshes, spring bogs, etc. The imagos are strong of flight, and are oftenest seen coursing back and forth over some small stream, flying on a regular beat, and passing and repassing the same point at intervals of a few minutes. The collector may take advantage of this habit, and so station himself that he may reach the specimen as it passes, and capture it, if dextrous with a net.

Fig. 15 Tachopteryx thoreyi Selys; *a* bium and *b* antenna of a female nymph (Mr Williamson's type)

The nymphs live on the bottom in shallow water, buried in clean sand or in vegetable silt. Though buried they do not burrow, but descend by raking the sand from beneath them by sweeping, lateral movements of the legs. When deep enough, they kick the sand up over the back till only the elevated tips of the eyes and the respiratory aperture at the tip of the abdomen are exposed. By placing a live nymph in a dish of sand and water and watching, its method may be observed in a very few minutes. The whole comical performance reminds one strongly of the descent of an old hen in a dustbath.

Once adjusted in the sand, a nymph (unless food tempts) remains motionless a very long time. In a dish of sand on my table, I have had a nymph remain without change of position for weeks, no food being offered it. Let any little insect walk or swim near the nymph's head,

and a hidden labium springs from the sand with a mighty sweep and clutches it. I fed to a nymph of Cordulegaster diastatops 14 full grown nymphs of Capnia in rapid succession, which should represent a bulk about equal to that of the nymph that ate them. It ate a dozen quickly, the last two more slowly: it had been without food several weeks. Nymphs of the species described below as C. maculatus supposition, at Saranac Inn, captured and ate young brook trout as long as themselves, when placed in their cage. So eager were they, they would rise partly from the sand on approach of a trout. Like the nymphs of the Aeschninae, they seem to have a decided preference for big game, if one may judge by the strenuous efforts they put forth when something at the limit of their capacity for capturing approaches.

Our species belong to a single genus.

## CORDULEGASTER Leach

Of the seven species occurring north of Mexico six are found in the eastern United States, and of these six, five are likely to be found in New York state when careful collecting is done for them. But two of these, C. erroneus (from Keene valley) and C. diastatops, are on record from the state; a third, C. maculatus is recorded below from Saranac Inn.

Imagos of the six species of the eastern United States may be separated by the following table:

*a* Eyes not contiguous; the proximal inferior tooth of the superior abdominal appendage of the male almost completely incased within the 10th segment (subgenus Zoraena)

*b* Abdomen with yellow lateral spots; stigma brown.......... diastatops

*bb* Abdomen with yellow half rings; stigma yellow .................. sayi

*aa* Eyes contiguous; proximal inferior tooth of superior appendage of male more or less completely exposed

*b* Two cubito-anal cross veins before the triangles; triangle open, or divided by a single cross vein; stigma moderate (subgenus Cordulegaster)

*c* Abdomen with yellow lateral spots ..................... maculatus

*cc* Abdomen with yellow half rings ......................... erroneus

*bb* Usually three cubito-anal cross veins before the triangle; triangle often divided by more than one cross vein; stigma very long (subgenus Taeniogaster)

*d* Abdomen with lateral yellow spots (southern)............. fasciatus

*dd* Abdomen with a middorsal line of spots.................. obliquus

### ARTIFICIAL KEY TO THE SAME SPECIES

*a* Abdomen with a middorsal line of spots........................ obliquus

*aa* Abdomen with yellow half rings on the segments

*b* Face yellow ................................................... sayi

*bb* Face blackish.......................................................... erroneous
*aaa* Abdomen with lateral spots
*c* Abdomen 65 mm or more in length (southern)................ fasciatus
*cc* Abdomen less than 60 mm in length
*d* Spots single on sides of abdominal segments.............. diastatops
*dd* With large, separate, median and apical spots on sides of middle abdominal segments ........................................................ maculatus

As to the nymphs, few of them are known. Cabot[1] has figured and described as C. sayi (supposition) nymphs, which, later, Hagen[2] has referred to C. diastatops (supposition). These nymphs were from Maine, Massachusetts, Maryland and Virginia. It is very doubtful whether C. sayi occurs so far north as Massachusetts: owing to confusion of species, published records of distribution of our species of Cordulegaster need sifting. I have bred C. diastatops at Ithaca, and my nymphs agree with Hagen's description, and thus confirm his supposition. In the above cited paper Dr Hagen also published brief descriptive notes on two other Cordulegaster nymphs which he referred by supposition to C. dorsalis (of the Pacific slope) and C. obliquus (the latter one, a single imperfect specimen from Texas). This is all that has been published concerning the nymphs of American species of this genus.

I describe below nymphs of C. diastatops (raised) and C. maculatus (supposition), and in order to avoid repetitions, I will give herewith a general statement of the characters of nymphs of the genus: they are all very much alike.

Nymphs of this genus agree in the following points: the body is stout, rough, hairy, cylindric, tapering beyond the middle of the abdomen to a pointed apex, the longitudinal axis upcurved at both ends, the tips of the eyes and the abdominal appendages being the highest points. The antennae are seven-jointed, slender. The eyes cap the angular antero-lateral prominence of the head and extend a pair of sharp points internally on the vertex from their hind angles. Hind angles of the head rounded, the hind margin not obviously concave posteriorly. The labium is very large, extending posteriorly between the bases of the middle legs, its dilated, spoon-shaped anterior end covering the face up to the antennae, and meeting above a convex frontal prominence, whose margin is fringed with sensory hairs. The mentum is triangularly widened beyond the middle; its median lobe is produced in a median tooth which is bifid on the median line; its lateral lobes are broad, triangular, concave, and bear a row of short raptorial setae just within the external margin, a stouter, but not longer movable hook at the end of this row, and a series of coarse, irregular interlocking teeth on the distal margin.

1 Immature state of the Odonata. 1872. pt 1, p. 13, pl. 3, fig. 2.
2 Monograph of the earlier stages of the Odonata, Am. ent. soc. Trans. 1885. p. 290.

Prothorax with a transverse dorsal flattened area, which is fringed with stiff hairs; legs slender and not very long, adapted, not for running as stated by Hagen (*loc. cit.* p. 288), but for raking the sand aside; femora and tibiae with dorsal and ventral rows of long hairs, the ventral row on the tibiae graduating into spines at the tip, these becoming arranged in a double row on the ventral side of the tarsal segments; tarsi three-jointed; wings a little divergent on the two sides, when grown, reaching the fourth abdominal segment.

Abdomen, subcylindric, arcuately upcurved toward the tip; no dorsal hooks; lateral appendages less than one fourth as long as superior and inferiors; the transverse apical rings on the abdominal segments are somewhat remote from the apices of the segments and bear rows of very stiff hairs, which are incurved at the tip and serve to hold a layer of sand, dirt, etc. about the body.

The two species of nymphs described below may be easily separated as follows.

*a* Lateral margins of abdominal segments 8 and 9 sharp, ending posteriorly in stout triangular, conspicuous lateral spines........ diastatops (raised)

*aa* Lateral margins of abdominal segments 8 and 9 hardly acute, at their posterior ends a pair of minute, slender, cylindric, pointed spines, that are shorter than the hairs among which they are hidden........ maculatus (supposition)

Of the eggs of Cordulegaster I know nothing. Field observations are much needed on the matter of oviposition to observe whether they are dropped into the water, attached to supports, or inserted into plant tissues, and, if the latter, how the long, imperfect ovipositor of the female is used.

## Cordulegaster maculatus Selys

1854 Cordulegaster maculatus Selys, Acad. Belg. (2) Bul. 21:105

1861 Cordulegaster maculatus Hagen, Synopsis Neur. N. Am. p. 115

1875 Cordulegaster maculatus Hagen, Bost. soc. nat. hist. Proc. 18:50 (bibliography and distribution)

1893 Cordulegaster maculatus Calvert, Am. ent. soc, Trans. 20:246 (description)

This species was not uncommon at Saranac Inn. It was to be seen during the greater part of the summer on sunshiny days coursing up and down Little Clear creek on the hatchery grounds: it was observed nowhere else. It has not been reported from New York state hitherto.

The nymphs referred to this species by supposition (none of them being reared) were common in the sandy bed of Little Clear creek, in the places over which the imagos were observed flying; but one species was seen; that is the reason for referring the nymphs to this species. A number of exuviae were found on the edges of the fish ponds within a few days after our arrival, but none appeared later, and, though nymphs apparently fully grown were repeatedly taken and a good many of them kept in our cages through the remainder of the season, none of them trans-

formed. I believe that the season for their transformation was past and that the period of adult life for this insect is a long one. The few specimens captured were all males.

**Nymph.** Measures in total length 41 mm; abdomen 30 mm; hind femur 6 mm; width of head 7 mm, of abdomen 8 mm.

Body very densely rough hairy; colors (entirely obscured except after molting) yellowish marked with brown spots; a pair of these at the base of the fore wings, a double submedian row along the dorsum of the abdomen, oval, with apices convergent in each pair: external to these, another row each side with apices divergent; external to these, a less conspicuous row each side, of spots lying nearer the bases of the segments; superior and inferior appendages yellow, black tipped, fringed densely on their internal margins with soft black hairs; laterals one fifth as long, not fringed.

Fig. 16 Labium of nymph of Cordulegaster maculatus Say, supposition

Mentum of labium bell-shaped in outline (fig. 16); median lobe very long and dilated on the cleft apex in a pair of flat ovoid lobes, with serrulated margins and each with an external apical denticle; lateral lobe with 10 or 11 very unequal sharp teeth on distal margin, the longest of the teeth, the movable hook and the setae of about equal length, the hook several times as thick as the setae; setae five; setae on mentum 10 or 11, six or seven longer ones in a longitudinal row at the sides, and four small ones extending from the proximal end of this row toward the median line.

Abdomen with segments about equal in length as far as the 10th, which is about one third shorter; appendages equal the ninth segment in length; in the female the long triangular lobes of the ovipositor extend to the apex of the ninth segment, against which they are closely applied; lateral spines, minute cylindric pointed rudiments, hidden among the hairs of the lateral margins, on the eighth and ninth segments.

## Cordulegaster diastatops Selys

1854 Thecaphora diastatops Selys, Acad. Belg. (2) Bul. 21: 101

1886 Cordulegaster lateralis Scudder, Bost. soc. nat. hist. Proc. 10: 211

1872 Cordulegaster sayi (nymph) Cabot, Mus. compar. zool. Mem. v. 2, art. 5, p. 13, pl. 3, fig. 2

1885 Cordulegaster diastatops (nymph, supposition) Hagen, Am. ent. soc. Trans. 12:290 (description)

1878 Thecaphora diastatops Selys, Acad. Belg. Bul. p. 685 (descriptive notes and corrections)

1895 Cordulegaster diastatops Calvert, N. Y. ent. soc. Jour. 3:45 (listed from New York state)

This is a common species about the upland spring bogs near Ithaca and McLean N. Y. I have collected the nymphs by hundreds from the brownish vegetable debris of the puny streams trickling through such places.

The nymph differs from the preceding species in being a trifle smaller, and considerably less hairy; the lateral margins of segments 8 and 9 of abdomen are thin and sharp and bear sharp triangular spines; the labium is less widened just before the bases of the lateral lobes; the median lobe is less produced, more deeply notched in the middle, and the two lobes separated by this median notch are again cleft by a lesser notch.

Possibly these differences in median lobe of labium and in lateral margins of abdominal segments 8 and 9 may prove constant for the subgenera Zoraena and Cordulegaster.

## LIBELLULIDAE

*Skimmers*

This family is a host, and includes many of the commonest of our species. Most of them are of well sustained flight, and are seen continually hovering over the surface of still water, or are met with on the uplands while foraging. The females do not insert their eggs into the tissues of plants, but drop them loosely into the water, or hang them in strings about plant stems at the surface of the water.

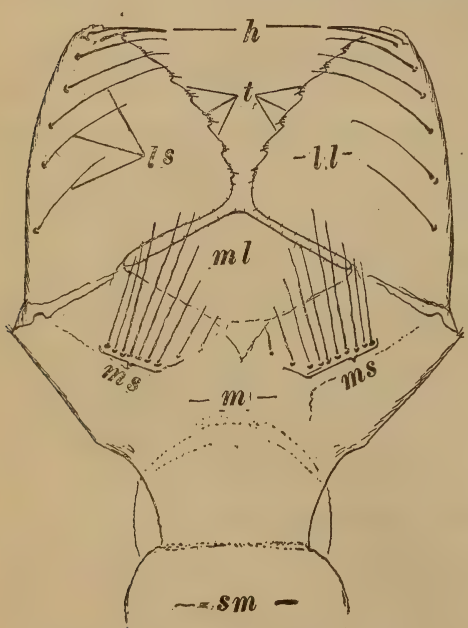

Fig. 17 Diagram of the Libellulid nymph labium (Perithemis domitia). *Sm* submentum; *m* mentum; *ms* mental setae; *ml* median lobe; *ll* lateral lobes; *ls* lateral setae; *t* teeth; *h* movable hook

The nymphs are sprawlers on the bottom, mainly in shallow water, or clamberers over fallen plant stems, and are protectively colored. They agree in the following characters: the labium (fig. 17) is masklike, spoon-shaped, with raptorial setae, and with its lateral lobe toothed on its distal margin; the antennae are seven-jointed, and setiform; the tarsi are three-jointed, with the third joint never as long as the two basal ones together; the wing cases are

long, reaching the sixth abdominal segment when the nymph is grown; lateral spines are present on abdominal segments 8 and 9, but the dorsal hooks are very variable, and often wanting.

Of the three subfamilies characterized below, the first one is here newly set apart; the other two are so closely allied that no single abso-

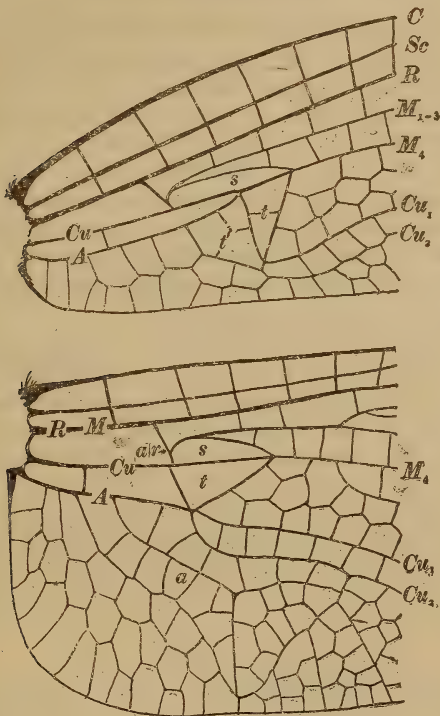


**Fig. 18** Bases of wings of Leucorhinia glacialis Hagen. *C* costa; *Sc* subcosta; *R* radius *M* media; *Cu* cubitus; *A* anal vein; *ar* arculus; *t* triangle; *t'* subtriangle; *s* supra triangle; *a* anal loop

lutely distinctive character has yet been found that will separate all the imagos. A combination of characters seems to be necessary for distinguishing both imagos and nymphs: a combination is therefore used in the following tables.

### KEY TO SUBFAMILIES

*Imagos*

*a* The triangle of the hind wing placed considerably beyond the arculus; the anal loop well developed, and hardly longer than broad; with more than two cubito-anal cross veins ....... ...................... Macromiinae

*aa* The triangle of the hind wing (fig. 18) retracted to the level of the arculus, or even passing it a little sometimes; the anal loop, greatly elongated (except in Nannothemis) and becoming foot-shaped: one or two cubito-anal cross veins.

*b* Sectors of the arculus (veins $M_{1-3}$ and $M_4$) distinctly separate at their departure from the arculus; anal loop elongate, but not distinctly foot-shaped, the toe part being little or not at all developed; the last antenodal cross vein extending from the costal to the radial veins (except in D. lintneri, in which it generally extends only from the costal to the subcostal); colors often metallic blue or green on thorax and abdomen Cordulinae p. 484

*bb* The sectors of the arculus in close apposition or completely fused for a little way beyond the arculus; anal loop generally distinctly foot-shaped, with well developed "toe"; the last antenodal cross vein often discontinuous at the subcostal vein........................... Libellulinae p. 506

*Nymphs*

*a* Head with a prominent pyramidal frontal horn; abdomen flat, and almost circular in outline as seen from above; legs long, giving a spiderlike aspect to these big nymphs; 10th abdominal segment well exposed, not telescoped in the apex of the ninth segment; teeth on the lateral lobes of the labium with deep incisions between them........... Macromiinae

*aa* Head without pyramidal frontal horn; abdomen less flattened, more elongate; teeth on the lateral lobes of the labium much wider than high.

*b* Lateral appendages of the abdomen more than half as long as the inferiors; hind femora longer than the head is wide; when the lateral spines are long (fig. 19*s*), then there is a full series of big, cultriform dorsal hooks on the abdomen .......................................... Cordulinae

*bb* Lateral abdominal appendages generally less than half the length of the inferiors; hind femora generally as long as the head is wide; often when the lateral spines of the abdomen are long the dorsal hooks are wanting or reduced ................................................ Libellulinae

## Subfamily MACROMIINAE

A small group of large species, more distinct than any other group within the family. The imagos are bulky and not very graceful, hairy and not strikingly beautiful in their coloration, but their flight is strong and well sustained: they glide through the air with the fearless abandon of masters of a situation.

The nymphs are quite unique in the family in the possession of a flat abdomen, almost circular in outline, recalling that of Hagenius, though less flat and circular than that, and an erect pyramidal horn on the front of the head; in this last character, they are unique among all Odonata. They lie flat on the bottom where there is little mud, or oftener, on some nearly bare ledge in the border of a stream, with their thin legs radiately arranged, and the body almost completely covered with silt. Thus they await their prey and seize it when it approaches. They are all an undetermined number of years reaching maturity.

Our two genera may be separated as follows:

*Imagos*

*a* Dorsal surface of the head with the occiput larger than the vertex; subtriangle of the fore wings usually divided by a cross vein; four to six cross veins in the space above the bridge (*see* fig. 9)............ Didymops

*aa* Dorsal surface of the head with the occiput much smaller than the vertex; subtriangle of the fore wings generally open; two or three cross veins in the space above the bridge............................Macromia

*Nymphs*

*a* Head hardly as wide across the eyes as across the bulging hind angles; lateral spines not incurved, those of the ninth abdominal segment hardly surpassed by the tips of the appendages; dorsum of the 10th abdominal segment with no trace of a dorsal hook...................... Didymops

*aa* Head widest across the eyes; spines of the ninth abdominal segment shorter, not nearly reaching the level of the apices of the appendages; dorsum of the 10th segment with a very rudimentary dorsal hook.......Macromia

### DIDYMOPS

There is a single species.

### Didymops transversa Say

1839 Libellula transversa Say, Acad. nat. sci. Phil. Jour. 8:19
1861 Didymops transversa Hagen, Synopsis Neur. N. Am. p. 135
1875 Macromia transversa Hagen, Bost. soc. nat. hist. Proc. 18: 57 (full bibliography, and distribution)
1890 Macromia transversa Cabot, Immature state Odon. pt 3, p. 14-16, pl. 1, fig. 3 (full bibliography, description of nymph and distribution)
1893 Didymops transversa Calvert, Am. ent. soc. Trans. 20:250 (description)
1899 Didymops transversa Kellicott, Odon. Ohio, p. 88 (description)
1900 Didymops transversa Williamson, Dragon flies Ind. p. 307 (description)

This is a common species in woodland streams and ponds, in water of a little depth, in shaded pools, etc., where there is little vegetation. It was not very common at Saranac Inn, but nymphs were taken in the borders of Little Clear pond and creek, and exuviae were found along the eastern shore of Lake Clear, hung up in the bushes, or attached to large rocks several yards from the water's edge. Imagos were observed only about the borders of the larger bodies of water. They could always be seen darting in and out of the edges of the woods on the fragrant shores of Little Green pond.

**Nymph.** (Pl. 18, fig. 8) Measures in total length, ♂ 27 mm, ♀ 29 mm; abdomen 19 mm; hind femur 11 mm; width of head 7 mm, of abdomen 13 mm. Body flat, thin edged, with legs wide apart at bases and sprawling. Color yellowish below, mottled brownish above, the

mottlings darker toward the middle line, and on the lateral ridges of the thorax; a darker band covering the top of the head, including the eyes, but not the frontal horn, which is yellowish, sprinkled on its upper side with brownish prickly granulations.

Head compact, bulging behind the eyes, which cap the elevated anterolateral angles; antenna with the basal segment twice as long as the second, about as long as the third; the succeeding segments gradually becoming a little shorter; hind angles of the head obtuse angled superiorly; rear of head a little concave; prothorax with a flat, angular fringed process each side, fitted snugly against the sides of the head; tarsi with the second and third joints of about equal length, the first joint about one third as long; femora and tibiae ringed obscurely with brown; wing cases reaching almost to the apex of the sixth abdominal segment.

Abdomen flat, with thin, flat lateral margins, and a median row of large, cultriform, dorsal hooks on segments 3-9, these same segments longer at the sides than on the median line; long, straight, lateral spines on segments 8 and 9, on 8 slightly divergent, on 9 parallel, as long as or longer than the body of the segment; 10th segment annular, inserted into an apical excavation of the ninth, one third as long as the length of the ninth on its middorsal line; appendages about as long as 9 above, subequal, or the laterals a very little shorter. Thorax broadly excavate below for the reception of the labium, with a pair of supporting humps beside it on the mesothorax and another one behind it on the metathorax.

Labium large; mentum broadly triangular, strongly contracted at its basal fourth, with a moderately prominent and declined median lobe, and about seven raptorial setae each side, the two inner ones quite small; lateral lobe ample, concave, with five raptorial setae and a hook that is stouter but little longer than the setae; distal margin with about six or seven crenate oval teeth, each bearing several graduated spinules.

### MACROMIA

Two species are regional, but only one of them has as yet been taken within the state (M. illinoiensis); the other (M. taeniolata) is found from Pennsylvania southward as far as Florida. Neither has as yet been bred. Cabot[1] has described nymphs referred by supposition to each. Till these are reared it is hardly worth while to repeat descriptions in detail. It will suffice to give a general account of the characters of nymphs of this genus, and to state in tabular form the chief differences between the two species of nymphs believed to be the two species named.

The nymphs of the genus are short and flat, with widely sprawling legs. The shape of the prominent eyes, elevated on the laterosuperior angles of the head, and of the frontal horn, offer specific characters: the head is widest across the eyes, and slowly narrowed behind them, to the obtuse hind angles, each of which bears a tubercle on its upper aspect. The wings reach well over the sixth abdominal segment. There are strong cultriform, dorsal hooks on abdominal segments 2–9, and there is

1 Immature state of the Odonata. 1890. pt 3.

a low median ridge representing another on the 10th segment, often little evident. The lateral spines, which occupy the sides of the eighth and ninth segments, are generally stout and flattened, and do not reach the level of the tips of the appendages. The 10th abdominal segment is a little shorter than the ninth.

*Imagos*

*a* Length of abdomen generally less than 50 mm; expanse of wing less than 100 mm; thoracic dorsum usually without yellow stripes ..... illinoiensis

*aa* Length of abdomen about 60 mm; expanse of wing more than 110 mm; dorsum of the thorax with a pair of short, yellow stripes....... taeniolata

*Nymphs*

*a* Lateral spines of abdomen directed posteriorly, hardly incurved; pyramidal horn on the front of the head acute at apex...illinoiensis, supposition

*aa* Lateral abdominal spines strongly incurved at the tip; pyramidal horn on the front of the head obtuse, hairy............ taeniolata, supposition

## Macromia illinoiensis Walsh

1862 Macromia illinoiensis Walsh, Acad. nat. sci. Phil. Proc. p. 397

1893 Macromia illinoiensis Calvert, Am. ent. soc. Trans. 20:251 (description)

1897 Macromia illinoiensis Van Duzee, N. Y. ent. soc. Jour. 5:89 (listed from Grand Island)

1899 Macromia illinoiensis Kellicott, Odon. Ohio, p. 87 (description)

1900 Macromia illinoiensis Williamson, Dragon flies Ind. p. 308 (description)

1890 Macromia illinoiensis (nymph supposition) Cabot, Immature state Odon. 3:16, pl. 1, fig. 2 and pl. 2, fig. 1

A species which ranges from New Hampshire to Texas. Though taken but once as yet within the state, it probably dwells in the borders of a number of our larger bodies of water. I have not seen the imago at large. I have seen a few of the nymphs referred to this species, and may add a descriptive note covering some points unnoticed by Cabot.

A nymph 26 mm long has a length of abdomen of 16 mm; of hind femur of 11 mm; a width of head of 7.5 mm, of abdomen of 11 mm.

Head a little narrowed behind the very prominent eyes to the hind angles, above each of which is a little superior tubercle; labium greatly widened anteriorly, and concave, forming an immense mask; lateral setae six, with two little axial setae at the base of the lateral lobe within; mental setae five each side, close together in row, with several more minute, detached ones nearer the median line; teeth about five, large, oblique, each armed with about four or five spinules.

The few nymphs I have found were all obtained from clayey banks among wave-washed roots of trees, in places most difficult to use a net.

### **Macromia taeniolata** Rambur

1842 Macromia taeniolata Rambur, Ins. Neur. p. 139
1861 Macromia taeniolata Hagen, Synopsis Neur. N. Am. p. 132
1874 Macromia taeniolata Hagen, Bost. soc. nat. hist. Proc. 16:359
1893 Macromia taeniolata Calvert, Am. ent. soc. Trans. 20:250 (description)
1899 Macromia taeniolata Kellicott, Odon. Ohio, p. 86 (description)
1900 Macromia taeniolata Williamson, Dragon flies Ind. p. 309 (description)
1890 Macromia taeniolata (nymph, supposition) Cabot, Immature state Odon. Pt 3, p. 9, pl. 2, fig. 4.

Distributed from Pennsylvania to Florida and Illinois.

#### KEY TO NORTH AMERICAN GENERA OF CORDULINAE (*s. str.*)

*Imagos*

*a* Veins $M_4$ and $Cu_1$ in the fore wing parallel or a little divergent apically, the number of rows of cells between them increasing toward the margin of the wing[1] .......... Neurocordulia

*aa* Veins $M_4$ and $Cu_1$ in the fore wing approximated toward the margin of the wing

*b* The second cubito-anal cross vein (and therefore, the subtriangle) normally present in the hind wing (absent occasionally in Helocordulia)[1]

*c* Triangle of hind wing divided by a cross vein .......... Epicordulia

*cc* Triangle of hind wing without cross vein, open

*d* Anal loop symmetrically truncated at its distal end, with but three cells at the end; stigma very narrow and sharp-pointed at its ends
Helocordulia

*dd* Anal loop unsymmetrically truncated at its distal end, with more than three cells at the end; stigma wider and less sharply pointed
Somatochlora

*bb* The second cubito-anal cross vein absent in the hind wing

*c* Triangle of the fore wing traversed by a cross vein, with two complete rows of cells in the space beyond it

*d* Wings with black basal markings; inferior appendage of the male, not bifurcated .......... Tetragoneuria

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1 One species, the little Cordulia lintneri of Hagen, may seem to belong in this section of the table, though, of course, not in the genus Neurocordulia; it is also a synthetic type, lacking the special corduline features of venation, which I take to be 1) the approximation of veins $M_4$ and $Cu_1$, and 2) the general reduction of cross veins; it shows strong libelluline affinities in the conformation of the anal loop and in the possession of a half-antenodal cross vein just before the nodus. We may expect that its nymph when discovered will throw light on its true relationships. I leave it here in the genus Dorocordulia beside the two species with which it has hitherto been associated.

*dd* Wings clear; inferior abdominal appendage of the male deeply bifurcated, the forks again notched at tips; never with less than five antenodals in the hind wing, or with the triangle of that wing traversed by a cross vein .......................... Cordulia

*cc* Triangles of the fore wings open .................... Dorocordulia

So well marked are these genera that they may generally be recognized at a glance by the following.

*Single distinctive characters*

Epicordulia alone has large brown spots at base, nodus and stigma of all wings.

Tetragoneuria alone has but four antenodals in the hind wing.

Helocordulia alone has the stigma very narrowly diamond-shaped, with the ends of it meeting the sides by an angle of 30°–35°.

Cordulia alone has the inferior abdominal appendage of the male deeply bifurcated.

Dorocordulia alone has the triangle of the fore wing free from cross veins.

Neurocordulia has been sufficiently distinguished above; Somatochlora possesses none of the characters of this list.

*Nymphs*

*a* Lateral setae four or five; mentum about as long as wide.. Epicordulia

*aa* Lateral setae seven; mentum of labium longer than wide

*b* Abdomen with large, laterally flattened, generally cultriform dorsal hooks

*c* Lateral spines of the ninth segment longer than half the length of that segment; dorsal hooks on segments 3–9, highest on 6, cultriform, and sharp ........................................ Tetragoneuria

*cc* Lateral spines of the ninth segment shorter than half of that segment; dorsal hooks less developed

*d* Dorsal hooks on segments 4–9 laterally flattened, but obtuse at apices, and not cultriform.................................. Somatochlora[1]

*dd* Dorsal hooks on segments 6–9, longest on 8 and cultriform Helocordulia

*bb* Abdomen with no dorsal hooks, or with these rudimentary, not flattened laterally or cultriform, but small obtuse or pointed prominences

*c* Hind angles of the head rounded; lateral spines of the ninth abdominal segment one fifth as long as that segment.................. Cordulia

*cc* Hind angles of the head angulate superiorly; spines of the ninth abdominal segment one third as long as that segment ....Dorocordulia

1 There can be little doubt that the unknown nymphs of the numerous species of this genus will necessitate an amplification of the characters herein stated. S. elongata appears to be the only American species yet reared. Cabot described a nymph as that of Som. albicincta, supposition, but I am unable to say whether the supposition was correct: so far as one may judge from his figure, that one might as well have been Cordulia shurtleffi. The typical Somatochlora metallica of Europe has dorsal hooks on segments 3–9 of abdomen, with the posterior ones better developed than in S. elongata. It must be borne in mind by those who use this table that it is based only on the nymphs of the species herein described.

### NEUROCORDULIA

No species of this genus has been taken within the limits of this state, but the following one is regional, being distributed from Massachusetts to Indiana. The nymph of the genus is unknown, unless the one described below be it. That nymph described and figured by Cabot and indicated as belonging possibly to this species, is Libellula pulchella.

## Neurocordulia obsoleta Say

1839 Libellula obsoleta Say, Acad. nat. sci. Phil. Jour. 8: 28
1839 Libellula polysticta Burmeister, Handb. ent. 2 : 856
1861 Didymops obsoleta Hagen, Synopsis Neur. N. Am. p. 136
1873 Epitheca obsoleta Hagen, Bost. soc. nat. hist. Proc. 15 : 269
1863 Cordulia modesta Walsh, Ent. soc. Phil. Proc. 2 : 254
1890 Epitheca obsoleta Hagen, Psyche, 5: 369, pl. 1, fig. 7-9 (critical notes, with figures of the accessory genitalia)
1893 Neurocordulia obsoleta Calvert, Am. ent. soc. Trans. 20: 252 (description)
1900 Neurocordulia obsoleta Williamson, Dragon flies Ind. p. 312

This species seems to be everywhere rare. I have not seen it at large. There are very few specimens in collections. It is very different in many particulars from all the other Cordulinae. It is very desirable that some one should rear it. The imago will be easily recognized by the characters given in the table. I describe below a nymph from Pennsylvania which probably belongs here.

**Nymph.** (Not grown) Measures in total length 18 mm; abdomen 8mm; hind femur 5 mm; width of head 5 mm, of abdomen 8 mm; length of body without antennae 17 mm.

A singularly flat-bodied, short-legged nymph with exceptionally contracted abdomen, smooth, blackish in color, with traces of paler bands on the femora and tibiae.

Head dorsally flattened, with a pair of low, submedian, vertical tubercles, and a shelf-like, scurfy pubescent frontal ridge, as long as the two basal segments of the antennae; antennae seven jointed; joint 1 cylindric, 2, globular, these of equal length; segments 3-7 slightly decreasing in length to the conic seventh segment. Hind angles of the head obtuse, but prominent posteriorly, overhanging the front of the prothorax; hind margin of the head excavate between the hind angles.

Labium short and broad, hardly extending posteriorly beyond the bases of the fore legs; mentum broadly triangular, contracted at its base, concave within, its sharp superolateral margins spinous at both ends; median lobe moderately prominent, with a few minute spinules on the front border of it, declined; mental setae eight or nine, the three or four innermost ones quite small each side; lateral lobes triangular, concave within, its distal border cut in about seven semi-elliptic teeth, each armed at its tip with two or three spinules, lateral setae five; movable hook a little longer and stronger than the setae, gently arcuate.

There is a distinct occipital ridge on the rear of the head below the level of the vertex, closely applied to a corresponding ridge on the front

margin of the prothorax. The dorsal shield of the prothorax farther bounded on the posterior side by a transverse ridge, which curves forward at its ends to terminate in a pair of prominent lateral processes; there is also an obtuse supra-coxal process each side which extends forward close beside the head halfway from the hind angles of the head to the eyes.

Body depressed; legs smooth, wide apart, the three pairs successively more remote from each other at base, the middle and hind femora each with a superior ridge, the fore and middle tibiae each with a ridge, starting at its base exteriorly (dorsally) and at once curving to extend down its anterior face; tarsi three-jointed, the third joint about as long as the two basal together, the claw short and stout, about as long as the basal joint.

Abdomen flat, suborbicular, granulate, with a row of oval smooth scars midway between the median line and the lateral margin each side on segments 4–8; wing cases reaching but to the middle of the fourth abdominal segment (the nymph is apparently not grown); there is a row of conspicuous dorsal hooks starting from between the wing cases and ending on segment 9; strongly flattened laterally, not hooked at all, but erect, and rounded on tips, highest on the sixth segment; ventral sutures wide apart, slightly convergent posteriorly, disappearing on the ninth segment; basal abdominal segments extremely contracted, segment 1 telescoped by the metathorax, visible only in the middle of the ventral side; genitalia (♂) visible at the midventral apex of segment 2; lateral spines on 8 and 9, long and sharp, divergent on 8, parallel on 9 and as long as the segment, greatly surpassing the appendages; segment 9 excavate above between the lateral spines, to inclose the annular 10th segment and the appendages, one half as long on the middorsal as on the midventral line; inferior appendages about as long as segment 9 is on the dorsal side, the superior and the laterals successively shorter, the latter a little longer than half the inferiors; segment 10 about half the dorsal length of the ninth segment; inferior apical and lateral margins of the ninth segment fringed with long hairs.

A single nymph[1], sent me by Dr Calvert, from the collection of the Academy of natural sciences of Philadelphia, bearing the label, "H. C. Borden, Pa. Oct. 26, '95".

The flat abdomen with erect blunt dorsal hooks and smooth lateral scars, and the elongate third tarsal segment recall Hagenius, while the broad mask-shaped labium, the vertical tubercles and the frontal ridge recall Epicordulia. The transverse occipital ridge, the curving carina on the fore and middle tibiae, and the extreme abbreviation of the basal abdominal segments are characters which I do not recall having observed in any other nymphs whatever.

1 Since the above was written I have received exuviae from Dr Calvert, taken at White lake in the Catskills, and from E. B. Williamson, taken at Nashville Tenn., of this same species. The length of the nymyh when grown is 21 mm. I now feel quite certain that these belong to Neurocordulia.

## EPICORDULIA

We have a single species.

### Epicordulia princeps Hagen

*Water prince* (Pl. 22, fig. 1)

1861 Epitheca princeps Hagen, Synopsis Neur. N. Am. p. 134
1875 Cordulia princeps Hagen, Bost. soc. nat. hist. Proc. 18:61 (bibliography)
1893 Epicordulia princeps Calvert, Am. ent. soc. Trans. 20:251 (description)
1899 Epicordulia princeps Kellicott, Odon. Ohio, p. 88 (description)
1900 Epicordulia princeps Williamson, Dragon flies Ind. p. 310 (description)
1890 Epitheca princeps Cabot, Immature state Odon. pt 3, p. 25, no. 12, pl. 3, fig. 3 and no. 13, pl. 4, fig. 3 (*juv.* nymph)
1889 "Libellulina nymphs nos. 10 and 12." Garman, Ill. state lab. nat. hist. Bul. 3, 3:179

This species is distinguishable from all the following even in flight by its large size and its brown wing blotches at nodus and stigma. It is a widely distributed species, locally common where there are ponds or sluggish streams with muddy, reed-grown banks. Imagos appear on the wing in May and continue flying through midsummer. They seem absolutely tireless in flight; very rarely indeed is one seen resting. The males at least prefer the surface of still water, over which they will sweep back and forth in zigzag lines and broad curves hour after hour.

The nymphs sprawl on the bottom amid fallen reeds, or clamber over submerged logs. In winter I have found numbers of them crowded in the crevices of a submerged stump.

Transformation takes place very early in the morning. The nymphs will crawl several meters from the edge of the water if necessary in order to find a proper support. They are stiff creatures with legs set wide apart, and, not being good climbers of reeds, generally seek some broader supporting surface, such as the side of a stump, or a cluster of grass blades. The eggs are dropped by the female while flying alone, dips being made far out in open water, and widely distributed.

**Nymph.** (Pl. 21, fig. 2) Measures in total length 27 mm; abdomen 17 mm; hind femur 8 mm; width of head 7.5 mm, of abdomen 8 to 12 mm, there being very great variation in this last measurement.

Since this nymph has been figured and described by Cabot, it will suffice here to give a brief statement of the more distinguishing characteristics. Head a little narrowed behind the small eyes, which cover the anterolateral angles; there is a pair of low conic tubercles on the top of the head, these larger in younger nymphs, and sometimes even cultriform. The statement that the young nymphs of this species do not differ

from the grown nymph in this respect is sometimes (but very rarely) true. Labium with four (less often five) lateral setae, and four larger mental setae each side, with one or two lesser ones near the median line. Thorax with broad sterna.

Abdomen depressed, triquetral; dorsal hooks large, cultriform, in a very regular series, on segments 2–9; lateral spines on segments 8 and 9, those of the ninth segment surpassing the level of the tips of the appendages; superior appendage very nearly as long as the inferiors, laterals a little more than half as long as the inferiors.

There are two indistinct and interrupted bands of brownish markings, extending from the hind angles of the head to the bases of the spines on the ninth abdominal segment, and there are darker rings on tibiae and femora, discoverable specially after molting.

This species was seen but a few times at Saranac Inn, and no specimens were taken either as nymphs or imagos. It is not uncommon in other places in the state, and will probably be found quite generally distributed when proper search is made for it.

### TETRAGONEURIA

This North American genus is one of the most important, most generally distributed, and most common in the subfamily. The imagos are somewhat scarce in collections, but they are by no means so in nature. Because of their superb aerial powers they are not often taken in flight. They depart widely from the regular haunts of the less active species while foraging, and thus often escape the specialist who is collecting for dragon flies in particular. The roving habits of the imagos account sufficiently for the wide distribution of most of our species.

About an Illinois pond in which Epicordulia princeps and Tetragoneuria cynosura were the only Cordulinae present, I have watched day after day the little Tetragoneuria chasing the big Epicordulia about in air, much as a kingbird chases and harasses a crow, surpassing by its swiftness and by its ability to make quick turns in air.

Nymphs of this genus may be found in almost any pond; they are often found in enormous numbers. By far the easiest way to get imagos is to capture well grown nymphs and rear them.

Nymphs of this genus agree so closely that I give here a general account of them, which, for specific descriptions will only need to be supplemented by the specific characters stated in the following table; the differences therein stated are the only differences I know between the species.

The nymphs are trim and smooth, with depressed abdomen and long lateral spines. The general color is greenish or yellowish, with a

longitudinal band of brown each side of the thorax, rings on femora and tibiae, and obscure, interrupted, longitudinal rows of spots on the abdomen. Head compact, with eyes very prominent laterally, and the front somewhat swollen between the bases of the antennae; labium with its mentum distinctly longer than wide, the median lobe prominent, declined, minutely spinulose on its front border, with two stouter spinules at the sides of the apical angle; lateral setae seven; mental setae six to nine; movable hook slightly incurved, and sharply pointed; teeth crenate, spinulose.

Abdomen roof-shaped; segments 3-9 about equal in length, the 10th a minute annular segment almost included within the apex of the ninth; dorsal hooks on segments 2-9, spine-like anteriorly where covered by the wings, distinctly cultriform posteriorly; lateral spines on segments 8 and 9 long and broad at base.

Four species are tabulated below: one of these, T. spinosa, has not been hitherto recorded from this state. These four were all common at Saranac Inn, excepting the typical T. cynosura. So common were they, in fact, that I stumbled on two desirable bits of information concerning the genus that I should probably have missed had they not been very common. The first of these relates to the proportionate abundance of the sexes. Males mainly are collected by the ordinary methods; and for half a century or more students of the group have been remarking on the striking preponderance of males in this and other genera. I collected on Blueberry island in Little Clear pond in about 10 minutes 111 cast skins of T. spinigera and T. semiaquea, intermixed, taking them as they came, without any selection whatever. These were separated as to species and sexes (the males being easily recognized by the indications of the secondary genitalia on the ventral side of the second abdominal segment) and counted, with the following results: T. spinigera, ♂s 22, ♀s 24; T. semiaquea, ♂s 25, ♀s 40, in both cases a slight excess of females. I once counted a large number of skins of T. cynosura, and E. princeps taken from Purington lake at Galesburg Ill. I have not the figures resulting from the count, but I remember distinctly that there was in each case a slight excess of females. The females are more shy and seclusive, and therefore less often taken. My breedings have never revealed any material excess in numbers of either sex for any species; and these are certainly more reliable than chance captures in air.

An acquaintance with the eggs of Tetragoneuria was likewise almost forced on me. These are laid in strings, attached together in masses (as shown in fig. 19) and hung on partly submerged twigs at the surface of the water. These were very common objects about the shores of Little Clear pond. I did not see any of them laid. That they belong

to Tetragoneuria is, therefore, an inference: it is sufficiently justified by the following considerations.

1) Tetragoneuria was the only libellulid sufficiently common at the pond to have produced the enormous number of eggs observed there. I think one might easily have filled a barrel with the clusters that could have been picked up at the surface of this pond: the cluster shown in the figure (which was smaller than the average) contained about 110,000 eggs (counted in part, and estimated), and with its enveloping gelatin

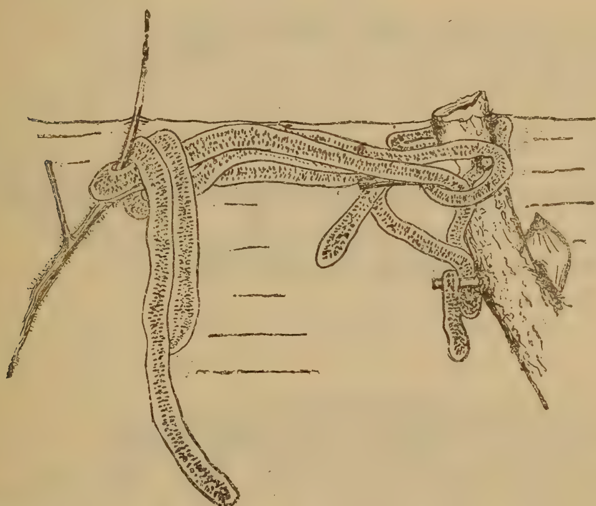

**Fig. 19 Eggs of Tetragoneuria hung on submerged twigs near surface of the water**

would have about filled a half pint measure. These clusters are doubtless the work of a number of females; the separate strings are often indicated by the ends left hanging free. These are undoubtedly libellulid eggs: none of our larger Libellulinae lay their eggs in strings; nor do the smaller Cordulinae, but the European genus Epitheca, not distantly related to Tetragoneuria, does so.

No other Cordulinae were common at this pond. I did not get more than a single nymph or imago of any other save Cordulia shurtleffi, and of that less than a dozen in all, there. But Tetragoneurias were abundant above all that I have ever seen elsewhere. They were scattered all about the margin excepting, perhaps, the bare shores of part of the north side, and were apparently rather uniformly distributed. I counted the number of cast skins of Tetragoneuria, without regard to species, clinging to the thin grass tussocks and fallen twigs along the water's edge for a distance of several rods at two places: at the north

side of the bay in Blueberry island, and on the outside of the cape which projects across the outlet, and found the number averaged 30 to a meter in distance along the shore line. When one reflects that there were miles of favorable shore line in this pond, the number of imagos suggested by a little calculation will account for a considerable quantity of eggs.

2) I hatched thousands of these eggs. While the nymphs of Libellulidae, when new-hatched, look much alike, these showed corduline characters quite as much like Tetragoneuria as any other.

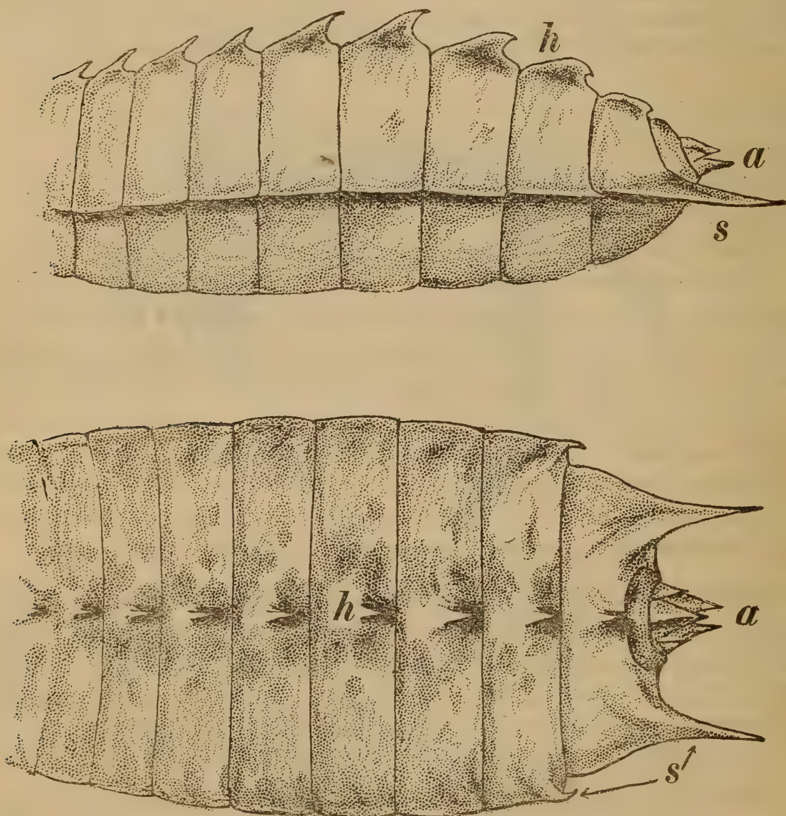


Fig. 20 Lateral and dorsal views of the abdomen of the nymph of Tetragoneuria cynosura Say. *a* Appendages *h* dorsal hooks; *s* lateral spines

Of the three species found at Saranac Inn I bred two species of the nymphs, and found other nymph skins which I have below referred by supposition to the other species (T. spinosa). The recognition characters for imagos and nymphs of the four species of the state are given below in tabular form.

### SPECIES OF TETRAGONEURIA

*Imagos*

*a* Frons with a black T-spot above; triangle of hind wings generally without a cross vein .................................................. spinigera

*aa* Frons without a T-spot above; triangle of hind wings generally traversed by a cross vein

*b* Superior appendage of the male not declined at tip, and without superior ante-apical spine. Hind wings generally with four antenodal cross veins.

*c* Hind wing with isolated basal streaks which hardly surpass the level of the first antenodal cross vein .............................. cynosura

*cc* Hind wings with broader, and more confluent markings, reaching the level of the third or fourth antenodal cross vein ........... semiaquea

*bb* The superior appendage of the male strongly declined at the tip beyond a superior ante-apical spine; hind wings generally with five antenodal cross veins, some of the antenodals surrounded by fuscous spots... spinosa

*Nymphs*

*a* Spines of the ninth abdominal segment strongly divergent, their tips distinctly wider apart than their bases on the outer sides....... spinigera

*aa* Lateral spines of the ninth segment, very slightly or not at all divergent

*b* Spines of the ninth abdominal segment longer than the segment

*c* Spines of the ninth segment hardly longer than is the segment on its dorsal side (fig. 20) ...................................... cynosura

*cc* Spines of the ninth segment one third to one half longer than is the segment on its ventral side ............................ semiaquea

*bb* Spines of the ninth segment distinctly shorter than that segment, and slightly incurved at tips..................... spinosa, supposition

## Tetragoneuria spinigera Selys

1871 Tetragoneuria spinigera Selys, Acad. Belg. (2) Bul. 31:269

1897 Tetragoneuria spinigera Van Duzee, N. Y. ent. soc. Jour. 5:90 (listed from Buffalo)

1897 Tetragoneuria spinigera Calvert, N. Y. ent. soc. Jour. 5:95 (listed from Buffalo)

1900 Tetragoneuria spinigera Williamson, Dragon flies Ind. p. 311 (description)

To the above record by Van Duzee of this species from Buffalo (repeated by Calvert in his list), I have to add two localities. It was exceedingly abundant at Saranac Inn during the month of June, flying about the grounds of the hatchery in company with the other two species occurring there—flying, also, about every other little clearing in the forest, foraging. It was very common toward the mouth of Buttermilk creek near Ithaca in June 1897.

## Tetragoneuria cynosura Say

*Dog-tail*

1839 Libellula cynosura Say, Acad. nat. sci. Phil. Jour. 8:30
1839 Epophthalmia lateralis Burmeister, Handb. ent. 2:847
1873 Cordulia cynosura Hagen, Bost. soc. nat. hist. Proc. 15:271
1861 Cordulia lateralis Hagen, Synopsis Neur. N. Am. p. 139 (description)
1893 Tetragoneuria cynosura Calvert, Am. ent. soc. Trans. 20:252 (description)
1895–97 Tetragoneuria cynosura Calvert, N. Y. ent. soc. Jour. 3:46 and 5:93 (listed from Ithaca, Lake George, Black Rock)
Tetragoneuria cynosura Kellicott, Odon. Ohio, p. 89 (description)
1900 Tetragoneuria cynosura Williamson, Dragon flies Ind. p. 311
1890 Epitheca cynosura (nymph) Cabot, Immature state Odon. pt 3, p. 28

This species, which has hitherto been recorded from but few localities within the state, is likely to be found in most large ponds in central and western New York. I have but one additional locality to record. I have received specimens from Prof. Herrick collected at Canandaigua.

I have not united with this species semiaquea Burmeister, notwithstanding that I think them one species showing racial variations, because there is no difficulty, so far as I have observed, in separating the imagos on the basis of the color distinction long in use, and because my bred nymphs do not agree very closely, and I have not had time for the study of a long series of these nymphs. I would call attention, however, to a fact indicating either that they will probably be found to intergrade, or that some one has made an error or mixed his specimens. Cabot described a longer and a shorter type of nymph of the straight-spined form: the one with the longer spines was bred and was T. cynosura; the one with the shorter spines was referred to T. semiaquea on supposition. From the shorter spined of my two with straight spines I bred abundantly in Illinois the typical T. cynosura. I have observed, however, that there is considerable variation in the length of these spines: there seems to be much less of it in their direction. While it seems likely that T. semiaquea will eventually rank as a race of T. cynosura, pending farther study, I have listed them separately here.

## Tetragoneuria semiaquea Burmeister

1839 Libellula semiaquea Burmeister, Handb. ent. 2:858
1842 Cordulia complanata Rambur, Ins. Neur. p. 145
1874 Cordulia semiaquea Hagen, Bost. soc. nat. hist. Proc. 16:360
1861 Tetragoneuria semiaquea Hagen, Synopsis Neur. N. Am. p. 140 (description)
1893 Tetragoneuria semiaquea Calvert, Am. ent. soc. Trans. 20:252
1895–97 Tetragoneuria semiaquea Calvert, N. Y. ent. soc. Jour. 3:46 and 5:93 (listed from Ithaca, Baldwinsville, Black Rock)

### **Tetragoneuria spinosa** Hagen

1878 Tetragoneuria spinosa Hagen, Acad. Belg. (2) Bul. 45; 188

This species was less abundant at Saranac Inn than the others of the genus mentioned as occurring there; but I captured at random a number of specimens of both sexes. The female shown in pl. 22, fig. 2, exhibits a singular type of coloration for this genus. The wings were of a rich flavescent brown, with spots of black on a number of the antenodal cross veins. This specimen I captured among the wild raspberry bushes near the house of the station agent at dusk, June 27.

Owing to the striking difference between the male appendages in this and the other species of the genus, there is probably no need here of a new description, notwithstanding that the original one in French seems as yet to be the only one, and it is not generally accessible in this country.

### HELOCORDULIA gen. nov.

The two species constituting this genus, C. uhleri Selys and C. selysi Hagen, have been included hitherto in the genus Neurocordulia. There is hardly another genus within the corduline series as here restricted, with which these have less affinity. A tabular statement of the differences between Helocordulia and Neurocordulia (as here restricted) with respect to wing venation will show the great discrepances for a single organ—the only one I have critically studied.

| CHARACTER | NEUROCORDULIA | HELOCORDULIA |
|---|---|---|
| Veins $M_4$ and $Cu_1$ | divergent apically with the cell rows between increasing from 2 to 5 | convergent apically with but two cell rows between |
| Stigma | broad and slightly oblique | narrow and very oblique at its ends |
| Antenodals of hind wing | five | six |
| Triangle of fore wing | of three cells | of two cells |
| Triangle of hind wing | of two cells | open; no cross vein |
| Apex of anal loop | with a long posterior angle, and at least five cells resting against the distal margin | squarely truncate or nearly so, with but three cells on the distal end |

Helocordulia is most nearly allied to Tetragoneuria. There are however a few venational characters which readily distinguish the two genera.

| CHARACTER | TETRAGONEURIA | HELOCORDULIA |
|---|---|---|
| 2d cubito-anal cross vein | absent | nearly always present |
| Under the stigma | a single cross vein followed by a wide space | two cross veins and more normal spaces |
| Antenodal cross veins of the hind wing | four or five | six |

The anal loop is slightly wider and more oblique at the apex in Tetragoneuria. T. spinosa has the antenodal cross veins spotted with fuscous much as in Helocordulia.

The nymph of Helocordulia is peculiar among the known corduline nymphs in having dorsal hooks on segments 6–9 only, with some

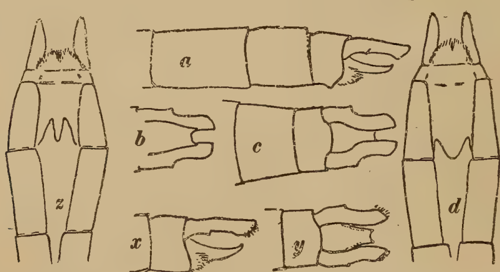


Fig. 21 Helocordulia, genitalia: *x*, *y* (♂) and *z* (♀) of H. uhleri Selys: *a*, *b* (ventral view), *c* (♂) and *d* (♀) of H. selysi Hag.

of these distinctly cultriform, and in the extreme abbreviation of the ninth abdominal segment on the dorsal side, so that its dorsal length is less than half its ventral.

The two species of the genus may be separated as imagos by reference to the figures herewith presented. The nymph is known for but one of these, H. uhleri, the only one apparently belonging to the New York fauna.

## Helocordulia uhleri Selys

1871 Cordulia uhleri Selys, Acad. Belg. (2) Bul. 21:274

1890 Neurocordulia uhleri Beutenmüller, Dragon flies vs mosquitos, p. 164 (listed from New York)

1895 Neurocordulia uhleri Calvert, N. Y. ent. soc. Jour. 3:46 (listed from New York)

This species was not uncommon in Little Clear creek on the hatchery grounds. Imagos were seen flying a few times about the banks of Little Clear pond close in shore and low above the water. They are so swift and agile, and their wings are so transparent that the eye follows them with difficulty. They are not very difficult to capture however, if one will place himself beside a regular "beat", and bring his net up behind the dragon fly with a quick stroke when it is passing. I found the imagos showing no disposition to avoid me even after escaping a stroke of the net several times. Twice I saw three males chasing one another up and down Little Clear creek, and had little difficulty in capturing them.

The nymph was not reared. Some of them, apparently about grown, were kept through the season without result. Apparently, the season for their transformation was over before any were found. There can be

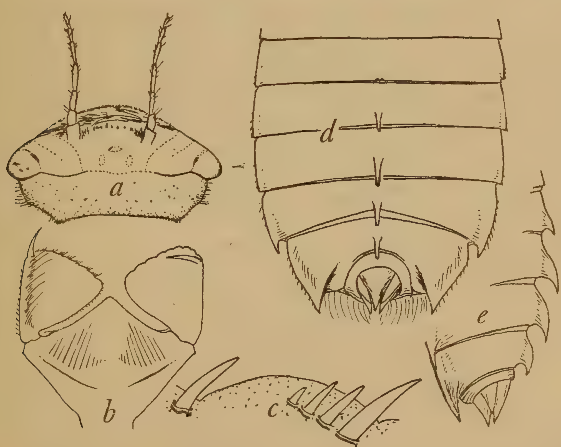


Fig. 22 Parts of nymph of Helocordulia uhleri Selys. *a* dorsal view of the head; *b* labium, from within, details in part omitted on the right; *c* a single tooth from the front border of the lateral lobe of the labium; *d* dorsal view of the abdomen; *e* lateral view of apex of abdomen, to show better the dorsal hooks

scarcely a doubt, however, as to the correctness of the reference of them to this species, when one considers that the only other corduline observed here like this one in size was D. libera, which I reared.

The nymphs live in the borders of the creek, mainly in the shallow places, filled with red-rotten vegetable debris — the haunts of the giant

crane fly, Tipula abdominalis, and the phantom fly, Bittacomorpha clavipes, larvae. But little collecting was done in such net-clogging situations, and hence, but a few of the nymphs were obtained. A single cast skin was found on a stump in the edge of a boggy place in Little Clear outlet, about eight inches above the surface of the water.

**Nymph.** Measures in total length 20 mm, abdomen 11 mm; hind emur 6 mm; width of head 5 mm, of abdomen 7 mm.

Color brownish, due to copious incrustation in all my specimens, with no visible color pattern.

Head compact, slightly broader than long; eyes only moderately prominent, with parabolic curve on the anterior side; antennae with segments about equal, the last, perhaps, a little shorter and pointed; labium reaching posteriorly between the bases of the fore legs and hardly beyond them; mentum triangular, channeled; the median lobe rather prominent, declined, fringed sparsely with short spinules along its fore margin; mental setae about 10 or 11, the fifth or sixth (counting from the side) longest; lateral setae seven or six, when seven the basal one smaller than the others; movable hook hardly longer than the setae, but much stouter; lateral lobe with about seven low crenate teeth on its distal border, each armed with two or three graduated spinules.

Prothorax with a prominent lateral process at each side of the dorsum and a similar anteriorly directed process above the fore coxa; legs slender and sparsely hairy; tarsi with the first joint about half as long as the second, which about equals the third in length.

Abdomen broadly oval, with dorsal hooks on segments 6-9, on 6 rudimentary, a mere low pointed tubercle, on 7-9 cultriform, largest on 8. Lateral spines on segments 8 and 9, a little larger on 9, short, triangular, sharp, those of 9 about one third as long as that segment, and about reaching the level of the tips of the appendages. Segment 10 is minute, annular, inserted into the apex of the ninth segment, which is less than half as long on its middorsal as on its midventral line; superior and inferior appendages about as long as segment 9 above, laterals one third shorter.

## SOMATOCHLORA

This genus is by far the largest in our corduline fauna. I have set apart three species hitherto placed in it, and, with these aside, it still comprises about half of the subfamily. The species seem to be common only in high altitudes in the northern part of the United States, and in British America. In all my collecting I have observed but one species in flight. This species was S. elongata, of which a few specimens were seen flying about the borders of Bone pond on Aug. 14. I obtained one nymph only of the species. That one was from Little Clear pond. From it I bred a fine male imago July 5. This seems to be the only specimen bred for all of our species; and so diverse are the imagos among themselves that the nymphs may hardly be expected to conform closely to the characters of this one in details. I give herewith figures of the

genitalia of both sexes of the five species listed below. These are the characters most used in characterizing them, and are the ones most reliable in determining specimens. These figures show the appendages to be unusually well marked with individuality. The nymphs of this genus offer an open field for study by collectors in boreal latitudes. Four species, tenebrosa, walshii, linearis and elongata, are recorded from the state. To this I have nothing to add but a new locality for the last named, and a partial life history of it. One other species occurs farther southward, and is almost certain to be taken in this state eventually, and is therefore included among the species listed below.

### Somatochlora elongata Scudder

Plate 21, fig. 15

1866 Cordulia elongata Scudder, Bost. soc. nat. hist. Proc. 10:218
1895 Somatochlora elongata Calvert, N. Y. ent. soc. Jour. 3:46 (listed from Ithaca)

The few imagos I saw of this species were flying with great swiftness about the borders of Bone pond. The single nymph I found was taken

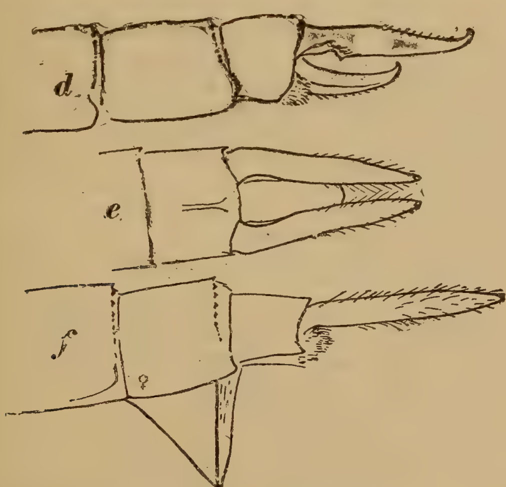


Fig. 23 Somatochlora elongata Scudd., end of abdomen; *d* and *e* of male; *f* of female

from Little Clear pond, as stated above, and transformed July 5. A cast nymph skin was found later in the season on the north side of the outlet of Little Clear, sprawling on a bed of moss but a few inches above the water line.

**Nymph.** Measures in total length 26 mm; abdomen 15 mm; hind femur 7.5 mm; width of head 7 mm, of abdomen 9 mm.

Body of the form of Cordulia, or slightly broader, sparsely hairy on appendages and margins; head with hind angles well rounded, the eyes moderately prominent; labium as in Cordulia, but with 13 or 14 mental setae, of which the fifth or sixth (counting from the side) is longest, the four or five internal ones being quite minute; lateral setae seven; teeth low, crenate, each armed with four or five graduated spinules.

Abdomen oblong, with not very sharp lateral margins, most narrowed posteriorly on the ninth segment; lateral spines on the eighth and ninth segments, those of the ninth segment about one fourth as long as the body of the segment; dorsal hooks on segments 4 to 9, small and erect points on segments 4 and 5, larger and laterally flattened and nearly equal on segments 6–9, but without sharp decurved apices; ninth segment about half as long on the middorsal as on the mid-ventral line, inclosing the annular tenth segment; lateral appendages hardly shorter than the equal lateral and superior appendages.

## Somatochlora filosa Hagen

1861 Cordulia filosa Hagen, Synopsis Neur. N. Am. p. 136

1893 Somatochlora filosa Calvert, Am. ent. soc. Trans. 20:253 (description)

1900 Somatochlora filosa Williamson, Dragon flies Ind. p. 313

m

n

o

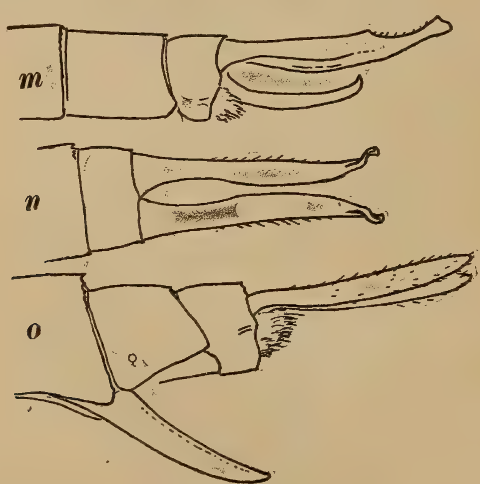

Fig. 24 Somatochlora filosa Hag., end of abdomen; *m* and *n* of male; *o* of female

This species is recorded from New Jersey and southward, and is very likely to be met with in New York state eventually.

Nymph unknown.

## Somatochlora linearis Hagen

1861 Cordulia linearis Hagen, Synopsis Neur. N. Am. p. 137
1893 Somatochlora linearis Calvert, Am. ent. soc. Trans. 20:253 (description)
1897 Somatochlora linearis Calvert, N. Y. ent. soc. Jour. 5:95 (listed from Oswego co., and Grand Island N. Y.)
1900 Somatochlora lateralis Williamson, Dragon flies Ind. p. 313 (description)

A species I have not met with. Its nymph is unknown.

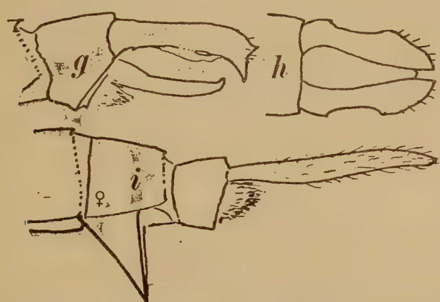

Fig. 25 Somatochlora linearis Hag. end of abdomen; *g* and *h* of male; *i* of female

## Somatochlora walshii Scudder

1866 Cordulia walshii Scudder, Bost. soc. nat. hist. Proc. 10:217
1897 Somatochlora walshii Calvert, N. Y. ent. soc. Jour. 5:95 (listed from Keene Valley)

Nymph unknown.

Fig. 26 Somatochlora walshii Scudd., *s* dorsal, and *t* lateral views of appendage of the male

## Somatochlora tenebrosa Say

1839 Libellula tenebrosa Say, Acad. nat. sci. Phil. Jour. 8:19
1861 Cordulia tenebrosa Hagen, Synopsis Neur. N. Am. p. 137
1895–97 Somatochlora tenebrosa Calvert, N. Y. ent. soc. Jour. 3:46 and 5:93 (listed from New York, Clarence and Oswego co.)
1900 Somatochlora tenebrosa Williamson, Dragon flies Ind. p. 314 (description)

Nymph unknown.

For location of descriptions of other species of the genus, some of which are likely to be taken in this state when careful collecting is done, consult the three bibliographic lists mentioned on p. 431.

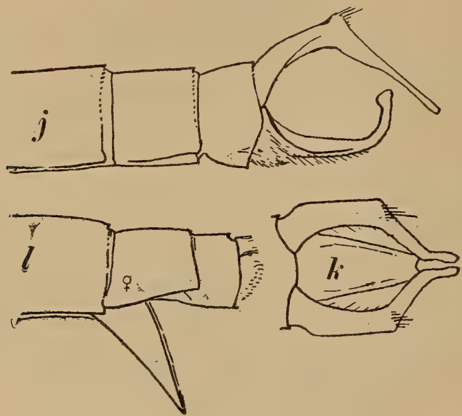


Fig. 27 Somatochlora tenebrosa Say, end of abdomen, *j* and *k* of male; *l* of the female (appendages omitted)

### CORDULIA

There is a single species belonging to our fauna.

## Cordulia shurtleffi Scudder

1866 Cordulia shurtleffi Scudder, Bost. soc. nat. hist. Proc. 10 : 217
1871 Cordulia shurtleffi Hagen, Bost. soc. nat. hist. Proc. 15 : 377

This species seems not to have been recorded hitherto from New York state. It was common at Saranac Inn. A few imagos were observed flying about the hatchery grounds, and along the creek, but their favorite resort for foraging and sport was the edge of a boggy pond hidden in the deep woods—such a pond, for instance, as the one a quarter of a mile south of the station, or the one north of the outlet of Little Clear pond back of the cabins. I spent a few of the pleasantest hours of the summer collecting on the springy border of the pond first named, immersed to the knees in the sinking sphagnum moss, a floating islet of sphagnum, decked with beautiful orchids, cut off by a narrow strait of clear green water at my feet. The Cordulias would fly along this strait between the islet and the moss on which I stood, and within reach of my net. There were generally a dozen or more about at a time, and one could be expected to traverse the strait every few minutes—often enough to keep a collector interested. So fleet are they, however, and so artful at dodging a net that generally a good many minutes elapsed between captures. Their flight is as free and graceful as their coloration is beautiful. Rarely was one seen to alight, but oc-

casionally one would sweep out into the forest and disappear among the hemlocks.

The nymphs obtained were gathered from a shaded trashy place in the edge of Little Clear pond and from Bone pond. They lie sprawling amid the trash after the manner of the better known Libellulas.

I did not rear these nymphs, the season of their transformation being over, apparently, before I obtained any of them. I kept a few in a cage through the greater part of the season: nevertheless, there is not the slightest doubt as to their identity. They agree very closely with the nymphs of the European C. aenea Linn., with specimens of which I have compared them. Male nymphs show in the stretched skin of the superior appendage the forked tip of the inferior appendage of the imago. The nymphs, like the imagos, were in numbers second only to the Tetragoneurias among the Saranac Cordulinae.

**Nymph.** Total length 21 mm; abdomen 12 mm; hind femur 6.5 mm; width of head 6 mm, of abdomen 7 mm.

Body elongate, sparsely fringed with coarse hairs on the appendages, edge of frons, rear of head, and lateral margins of abdomen; color greenish brown marked with blackish brown as follows: a tranverse band across the head including the eyes (almost divided by the median yellow ocellus when the nymph is grown) an urceolate median band on the prothorax not attaining its front margin, and divided by a fine yellow median line; a broad oblique lateral yellow band extending from above the base of the fore leg to the middle of the hind wing; below the last, a narrower parallel stripe above the base of the hind leg; a pair of submedian rows of blotches on the abdomen extending posteriorly from beneath the tips of the hind wings; and rings on femora and tibiae.

Head with the eyes laterally prominent and well rounded, hind angles obtuse and the hind margin slightly concave; no vertical tubercles; frontal ridge low obtuse; labium reaching posteriorly between the bases of the second pair of legs, triangular elongate, channeled above; median lobe prominent, declined; mental setae about 14, regularly graduated in size, the fourth (counting from the side) longest; lateral setae seven; movable hook hardly longer than the setae, nearly straight; teeth about nine, low, crenate, increasing in breadth inferiorly, each with several spinules.

Abdomen oblong, a little widened to the seventh segment, most narrowed apically on the ninth segment; 10th segment annular, half as wide as the ninth, and one fourth to one third as long as the ninth is on its middorsal line; ninth segment one half as long on the middorsal line as on the midventral; appendages almost equal, the superior and the laterals successively a very little shorter than the inferiors, which are about as long as segment 9 is on its dorsal side; lateral spines on segments 8 and 9 very short (about one fifth the length of the body of the segments which bear them), but pyramidal.

The first cast nymph skin was obtained June 16. The imagos were flying commonly throughout the month of July.

## DOROCORDULIA gen. nov.

Cordulia libera Selys, type

The three species here separated from Somatochlora and placed in this new genus differ from Somatochlora by a number of important venational and other characters, among which are the following:

1 The triangle of the fore wing is open: it is traversed by a cross vein in Somatochlora.

2 There are never more than two complete rows of cells beyond the triangle in the fore wings: there are more than two in Somatochlora.

3 The second cubito-anal cross vein (and, therefore, an internal triangle or sub-triangle) is wanting in the hind wing; it is present in Somatochlora.

4 There is a long space beyond the single cross vein under the stigma: in Somatochlora the spaces are more nearly equal, and there are often two cross veins under the stigma.

The Cordulia lintneri of Hagen may not belong here: in fact it may belong in the subfamily Libellulinae. I leave it here beside the species with which it has been associated pending farther study, and awaiting the discovery of its nymph. It will be found not to agree with characters 2 and 4 of the above statement.

This genus is more closely allied to Cordulia than to Somatochlora, but it differs from Cordulia by characters 1 and 2 as stated above, as well as by the lack of the deep bifurcation of the inferior appendage of the male which is characteristic of Cordulia. The nymph also, I found much more easy to distinguish from that of Somatochlora elongata than from that of Cordulia shurtleffi. The nymph is known for the single species D. libera.

Our imagos are readily separable into species by the following key:

*a* Abdomen with segments 7 to 10 spatulately dilated................libera
*aa* Abdomen gradually and very moderately widened at apex
  *b* The articulations of the abdominal segments yellow..............lepida
  *bb* The articulations of the abdominal segments not yellow.......lintneri

### Dorocordulia libera Selys

1871 Cordulia libera Selys, Acad. Belg. (2) Bul. 21:262

1895 Somatochlora libera Calvert, N. Y. ent. soc. Jour. 3:46 (listed from the Catskill mountains)

This dainty and beautiful corduline species was not uncommon at Saranac Inn. But few specimens were taken, because no special effort was made to get them. The imagos obtained were taken when flying with Cordulia shurtleffi about the borders of the bog ponds mentioned under the account of that species. They are less swift of

flight than that species, but they dash along shore on shining, transparent wings, dancing in and out of the little coves in the edge of the sphagnum fringe, and once in a while are seen resting on the tall summit of some pitcher plant flower.

The one nymph I obtained was taken from the edge of Little Clear pond at the outlet, and was reared, transforming July 7. From that cast skin the following description of the nymph was drawn up. The

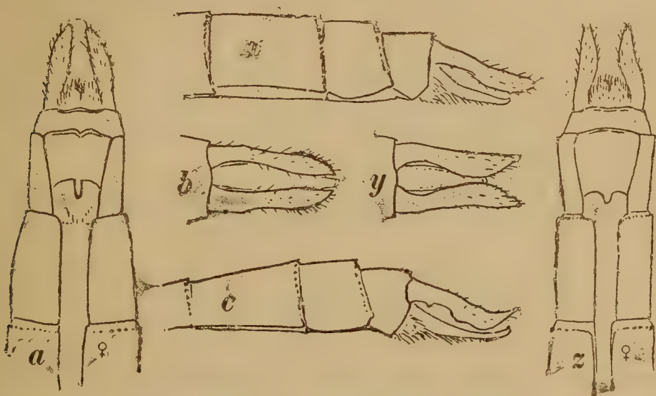


Fig. 28 Dorocordulia, end of abdomen. *a*, *b* and *c* of D. libera Sel.; *x*, *y* and *z* D. lepida Hag.

specimen is in the New York state collection at Albany. The study of this specimen, which was preserved and labeled by myself with such promptness and care as to preclude error or confusion of species among my specimens, reveals an error in Cabot's work on the corduline nymphs. The one he described as Som. libera, raised, can not have been of that species. I have not seen his specimen, but both his description and his figure disagree utterly with my specimen. They agree quite well with the nymph of Helocordulia uhleri, and I think they may have belonged to that species or to H. selysi.

**Nymph.** Total length 21 mm; abdomen 11 mm; hind femur 6 mm; width of head 5.5 mm, of abdomen 7 mm.

Very similar to the nymph of C. shurtleffi, but smaller, and with the black band across the head broader between the eyes, the eyes themselves more prominent laterally, and the hind angles of the head more angulate; labium similar; lateral setae seven; mental setae 12–13, each side, the fifth (counting from the side) longest, the others regularly grading up to it; abdomen similar, but the very rudimentary dorsal hooks a little more prominent on the middle segments (perhaps a little less obscured by tufted hairs about them); lateral spines longer on segments 8 and 9, about a third the length of their respective segments; inferior appendages longer than the superior, which in turn is longer than the laterals.

## Dorocordulia lepida Selys

1871 Cordulia lepida Selys, Acad. Belg. (2) Bul. 31: 264
1872–75 Cordulia lepida Hagen, Bost. soc. nat. hist. Proc. 15: 270 and 18: 60
1895 Somatochlora lepida Calvert, N. Y. ent. soc. Jour. 3: 46 (listed from Albany)

This species was originally described from specimens sent from Albany; it seems not to have been taken in the state since that time. Its nymph is unknown.

## Dorocordulia lintneri Hagen

1854 ——— ——— Emmons, Agric. N. Y. v. 5, pl. 15, fig. 1 (colored fig.: no name or description)
1878 Cordulia lintneri Hagen, Acad. Belg. (2) Bul. 45: 187
1890 Cordulia lintneri Hagen, Psyche, 5: 272, pl. 1, fig. 10-17 (a full account)
1895 Somatochlora lintneri, Calvert, N. Y. ent. soc. Jour. 3; 46 (listed from Center, Albany co.)

But few specimens are known of this very interesting species, which has a distribution from New York to Saskatchewan. Its nymph is unknown.

### Subfamily LIBELLULINAE

This extensive group includes the commonest and best known of all our Odonata. The imagos are familiar figures above every pond and ditch, and by every roadside. The nymphs are less well known, notwithstanding their relative abundance, than in some of the smaller groups. Our tables which follow are the first to be given for American forms, and the descriptions also are entirely new, with the exception of the nymphs of Pantala and Tramea, which alone have been described by Cabot. The following keys will serve for the separation of both nymphs and imagos.

#### KEY TO GENERA

*Imagos*

*a* Triangle of the fore wings four-sided; anal loop poorly developed, not foot shaped .................................... Nannothemis p. 509
*aa* Triangle of the fore wing fully differentiated, three-sided; anal loop well developed and foot-shaped
*b* Triangle of the fore wing with its front and inner sides meeting by an angle of about 100°; the subtriangle without cross veins; the vein which bisects the anal loop straight .................. Perithemis p. 511

*bb* Triangle of the fore wing with its front and inner sides meeting by an angle of about 90°; subtriangle divided into three or more cells; bisector of the anal loop sinuous

*c* Triangle of the fore wing not placed distinctly beyond the level of the apex of the triangle in the hind wing; pterostigma with its ends parallel or not distinctly divergent

*d* The sectors of the arculus (veins $M_{1-3}$ and $M_4$) in the fore wing more or less completely fused for a short distance beyond the arculus; the triangle of the fore wing not greatly produced posteriorly, and (except in Celithemis) normally containing but a single cross vein, and followed by two or three rows of cells

*e* Vein $Cu_1$ of the hind wing departing from the triangle at the hind angle

*f* Sectors of the arculus (veins $M_{1-3}$ and $M_4$) contiguous, but incompletely fused for a distance beyond the arculus; wings generally conspicuously spotted with yellow or reddish brown
Celithemis p. 513

*ff* Sectors of the arculus in the hind wing distinctly fused for a distance beyond the arculus

*g* Stigma short and thick, about twice as long as wide; anal loop with a big heel, there being generally four cells between the bisector and the heel point; face pure white
Leucorhinia p. 516

*gg* Stigma more than three times as long as wide; anal loop generally with but two cells between the bisector and the heel point
Sympetrum p. 519

*ee* Vein $Cu_1$ of the hind wing migrated a little way up the outer side of the triangle, separating itself at a distance from the hind angle

*f* With a single cross vein under the stigma, and a long vacant space before that cross vein ............ Pachydiplax p. 526

*ff* With two cross veins under the stigma and the adjacent spaces more normal

*g* With a single row of cells between veins $M_2$ and $Rs$
Mesothemis p. 527

*gg* With two rows of cells for a distance between veins $M_2$ and $Rs$
Micrathyria p. 528

*dd* Sectors of the arculus in the fore wing contiguous, but not completely fused beyond the point of their departure from the arculus; radial sector distinctly undulate (except in Ladona); triangle of the fore wing very much elongated posteriorly and narrow and generally traversed by two or more parallel cross veins, and followed by three to seven rows of cells

*e* Vein $M_{1a}$ arising under the proximal fourth of the stigma; fore wings with the subtriangle consisting of three cells, and the triangle followed by three rows of cells.................. Ladona p. 528

*ee* Vein $M_{1a}$ arising under the middle of the stigma; fore wings with the subtriangle consisting of four to 11 cells, and the triangle usually followed by four to six rows of cells

*f* Male with no ventral hooks on the first abdominal segment; female with the hind tibia a little longer than the hind femur; the sexes alike in wing pattern .......... Libellula p. 530

*ff* Male with a pair of ventral hooks on the first abdominal segment; female with the hind femur and tibia of equal length; wings dissimilarly colored in the two sexes ....... Plathemis p. 536

*cc* Triangle of the fore wing placed beyond the level of the apex of the triangle of the hind wing; stigma with its inner end perpendicular, its outer end very oblique to the bordering veins; wings broad at base and pointed at apex

*d* Radial sector regularly curved; hind wings with a broad, basal colored band.......................................... Tramea p. 537

*dd* Radial sector distinctly undulate; hind wings not covered at base by a broad colored band............................. Pantala p. 539

## *Nymphs*

*a* Unknown........................... Nannothemis[1] and Micrathyria

*aa* With large, cultriform dorsal hooks on abdominal segments 3-9; eyes small and situated on the midlateral margin of the head and directed laterally Perithemis

*aaa* With no dorsal hook on the ninth abdominal segment; eyes overspreading more or less the anterolateral margins of the head

*b* Basal segment of the hind tarsus more than half as long as the second segment; lateral appendages of the abdomen not more than half as long as the inferiors (except in Libellula quadrimaculata); superior abdominal appendage regularly tapering to a point

*c* Abdominal appendages strongly decurved; lateral spines wanting or extremely rudimentary.................................. Mesothemis

*cc* Abdominal appendages straight or very slightly declined; lateral spines evident on abdominal segments 8 and 9

*d* With no dorsal hooks at all; abdomen smooth, depressed; head twice as wide as long, with eyes very prominent laterally.. Pachydiplax

*dd* Dorsal hooks present, at least on the middle abdominal segments

*e* Abdomen ovate in outline, rather abruptly narrowed to the posterior end; hind margin of the eyes behind the middle of the head

*f* Lateral spines long and straight; abdomen not narrowed posteriorly before the eighth segment....................... Celithemis

*ff* Lateral spines shorter and more or less incurvate; the abdomen more or less narrowed before the eighth segment

*g* Dorsal hooks as long as the segments which bear them Leucorhinia

*gg* Dorsal hooks shorter than the segments which bear them Sympetrum

*ee* Abdomen lanceolate in outline, slowly narrowed to the pointed posterior end; eyes capping the prominent anterolateral angles of the head, their hind margin generally before the middle of the top of the head; body generally hairy

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1 Discovered since this key was prepared, and described below under the account of the genus.

*f* The 10th abdominal segment with subcarinate lateral margins; appendages very long; lateral setae 0-3.............. Ladona

*ff* The 10th abdominal segment shorter, cylindric; appendages shorter; lateral setae 5-10

*g* Head a little narrowed behind the eyes; front border of the median lobe of the labium entire................ Libellula

*gg* Head not narrowed behind the eyes to the hind angles; front border of the median labial lobe crenulate...... Plathemis

*bb* Basal segment of the hind tarsus half as long as the second segment; lateral appendages of the abdomen at least three fourths as long as the inferiors; lateral setae 10 or more; superior appendage of the abdomen suddenly contracted at its basal third, the dorsal two thirds forming a long slender point

*c* Movable hook of labium long and slender, setiform; teeth much broader than high; spines of the eighth segment one half longer than the ninth segment; superior abdominal appendage shorter than the inferiors Tramea

*cc* Movable hook of the labium short, hardly longer than the teeth; teeth higher than broad; spines of the eighth segment as long as the ninth segment; superior appendage equaling the inferiors ....... Pantala

### NANNOTHEMIS

There is a single species occurring within the state.

### Nannothemis bella Uhler

1857 Nannophya bella Uhler, Acad. nat. sci. Phil. Proc. p. 87
1861 Nannophya bella Hagen, Synopsis Neur. N. Am. p. 186
1867 Nannophya bella Packard, Am. nat. 1:311, pl. 9, fig. 6
1893 Nannothemis bella Calvert, Am. ent. soc. Trans. 20:260 (description)
1895 Nannothemis bella Calvert, N. Y. ent. soc. Jour. 3:48 (listed from Westchester co. and New York)
1900 Nannothemis bella Williamson, Dragon flies Ind. p. 327

This is apparently a somewhat rare species. I have not seen it alive. It is known to be distributed from Quebec and Indiana to Florida. Since the foregoing key was prepared its nymph has been discovered by Mr R. Weith near Elkhart Ind. and he has published some notes on the life history of the species and I have described the nymph (Can. ent. 1901. 33:252–255). Mr Weith's notes are abstracted below, and my own description and figure are appended.

This species occurs in very restricted areas (50 yards in length by 25 yards in width from margin of the lake) in two places near Elkhart Ind. Unlike most other Odonata, the imagos do not fly higher than a few feet above the ground, preferring to alight on marsh grasses and bask in the sunshine, where numerous small Diptera suitable for food

hover over the little stagnant pools. Nymphs were first found in small holes in the almost dry marsh land, too small to allow the use of a net and containing but a few inches of water. A larger number was obtained later from debris deposited in the marsh during high water and still submerged a few inches. Removed from the water the nymph clings closely to the debris of exactly its own color, and does not stir even after letting this dry; so it is very hard to see and a difficult subject for collection.

Fig. 29 Nannothemis bella Uhl. Nymph, labial lobe of nymph, and eggs

The females oviposit in the shallow places where the nymphs live, in temporary water of one to two inches depth, and very warm. The female dips the tip of her abdomen to the surface after the manner of all Libellulines, but only about three or four times; then rests; then repeats. The eggs are creamy white turning dark in a short time, and with scanty gelatinous envelop. (From the account by Mr Weith)

**Nymph.** (fig. 29) Fully grown, measures in total length of body 10 mm; abdomen 5.5 mm; hind femur 3.5 mm; width of head 3.5 mm, of abdomen 4 mm.

Color almost uniform tawny yellowish brown, paler below and on the sutures, more or less completely obscured by adherent vegetable debris. Body moderately hairy on lateral margins, specially hairy toward the end of the abdomen.

Head compact, one third wider than long, scurfy hairy above excepting a pair of bare spots near the hind margin, with prominent hemispheric, eyes covering the anterolateral angles, narrower behind the eyes with parallel sides, rounded hind angles, and almost straight hind margin.

Antennae shorter than the head is long, seven-jointed, with scattering hairs along the distal joints. Labium extending posteriorly between the bases of the fore legs; median lobe broadly triangular, half as long as wide, rounded on tip, with two spinules close together just before the tip, and several others each side along the front border farther apart; raptorial setae on the mentum, 10 each side, the fourth or fifth (counting from the side) longest, the three innermost ones quite small; lateral labial lobes ample, with six raptorial setae, and a spinule at the base; hook straightish to the slender slightly curved tip, hardly longer than the setae, but much stouter; teeth almost obsolete, bispinulose.

Prothorax with prominent spiracles; legs hairy, specially the tibiae externally; tarsal claws not strongly incurved; second tarsal joint one half longer than the first, and the third one half longer than the second; wings reaching well on the sixth abdominal segment.

Abdomen somewhat depressed, oblong, widest on the sixth segment, the ninth segment as wide as the second; narrowed with extraordinary abruptness on the 10th segment, which is almost included within the apex of the ninth. No dorsal hooks at all; in their places are tufts of a few long hairs, and whitish spots in the ante-apical membrane of the segments. Lateral spines on segments 8 and 9, hooklike, starting outward at base, and incurved at tip, on eight one half the length of the segment, on nine, a little longer than on eight. Hairs on the apical carinae well developed, specially so on segment nine, which they completely incircle, constituting a long fringe which completely overhangs the 10th segment and the appendages. Appendages about as long as the ninth segment is on its slightly shorter dorsal side; lateral appendages a third shorter.

Since the discovery and description of the nymyh of Tachopteryx thoreyi Selys by Messrs Graf and Williamson, last year, this species has remained the most important discovery to be made. It is our only representative of that singular group of Libelluline genera which Karsch called the Nannophyae.[1] Mr Weith's zeal and industry have brought this nymph to light, and there now remains of all the genera of Odonata of the northern United States and Canada but two in which no nymph are known, and they are Gomphaeschna and Micrathyria.

## PERITHEMIS

There is a single species occurring within the state.

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[1] Ent. Nachr. 15 : 245-63.

## Perithemis domitia Drury

Plate 24, fig. 3 and 4

*Amber wing*

I use the above scientific name in this place without having entered into the question of synonomy—a question for the determination of which I have no adequate material. Domitia is the name that has been used hitherto in most American descriptive papers. Dr Hagen regarded tenera and tenuicincta Say, chlora Rambur, metella Selys, and iris Hagen, as synonyms of domitia. Forms like those occurring in New York state were described by Say (1839) under two names, tenuicincta (♂) and tenera (♀). Should these be ranked as a species distinct from domitia the latter name, having precedence of position in Say's list, would be the name for the species. Hagen's *Synopsis of the Odonata of America*[1] and Kirby's *Catalogue of the Neuroptera Odonata*[2], represent the extreme views.

1773 Libellula domitia Drury, Illus. exotic ent. v. 1, pl. 47, fig. 4

1861 Perithemis domitia Hagen, Synopsis Neur. N. Am. p. 135

1893 Perithemis domitia Calvert, Am. ent. soc. Trans. 20:264 (description)

1895 Perithemis domitia Calvert, N. Y. ent. soc. Jour. 3:48 (listed from Westchester co.)

1898 Perithemis domitia Needham, Outdoor studies, p. 59, fig. 58 (♂) and 59 (♀)

1899 Perithemis domitia Kellicott, Odon. Ohio, p. 112 (description)

1900 Perithemis domitia Williamson, Dragon flies Ind. p. 317 (description)

This is a pretty, little brown species, with amber tinted wings. It is apparently not common in New York state, having been taken as yet only in the vicinity of New York city. I studied the species in Galesburg Ill., in 1895, and there worked out its life history.

It appears on the wing about the end of May, and flies through June. Its flight is rather weak, and a bit clumsy and slow. When over water it habitually avoids the altitude of the larger and stronger species, keeping down nearer the surface. It is very sensitive to cloudiness and moisture, being seldom seen in flight except when the sun is shining.

The female is sometimes held by the male while ovipositing, but I have seen her oftener unattended, dropping her eggs on bits of floating dead pond scum by many successive dips made at very nearly the same spot. When a female was taken in hand and "dipped" to the surface of water in a tumbler, 10 to 20 eggs were liberated by her at each descent.

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1 Bost. soc. nat. hist. Proc. 1875. 18:82–83.

2 1890, p. 10.

The egg (pl. 19, fig. 8) is oblong oval, at first white, turning brownish gray after a few hours; its surface is closely beset with minute tuberculate granulations. The gelatinous envelop is scanty.

The nymphs clamber about over trashy submerged vegetation; they climb well, but swim very poorly. They are cleaner and less sprawling than the Libellulas. The nymph goes no farther from the edge of the water to transform than is necessary to find a suitable place—generally but a few inches.

**Nymph.** Total length 15 mm; abdomen 9 mm; hind femur 5.5 mm; width of head 4.5 mm, of abdomen 6 mm.

Head wider than long, slightly concave behind, widest across the rounded eyes, which are at the middle of its length; labium (fig. 8A) short, not extending posteriorly beyond the bases of the first pair of legs; lateral setae five; mental setae about nine or 10, the two innermost ones minute and out of line with the others, the fifth (counting from the side) longest; teeth crenate, well marked, each armed with several spinules; hook short, little curved, differing much from the setae behind it in its greater thickness and less length.

Femora twice ringed with black; wing cases extending over the sixth abdominal segment.

Abdomen (fig. 8C) broad, depressed, triquetral, in outline oblong oval; lateral spines on segments 8 and 9, short; dorsal hooks on segments 3–9; these form a regularly descending curve, and, viewed laterally, look like a segment of a circular saw; superior and inferior appendages equal; the laterals half as long.

### CELITHEMIS

Two species of this genus, C. eponina and C. elisa, are known from this state, and a third, C. ornata, may be looked for toward the coast. These are three of the most beautiful among all our smaller species. Their colors are shades of black, red, yellow and brown; and the wings in all have a distinct color pattern.

The nymphs are known for the two species recorded from the state. They agree in having smooth bodies with depressed abdomen and long lateral spines. The head is wider than long, widest across the very prominent eyes, which at their sides are almost angulate, they project so sharply; the labium is very large, and has numerous very long and slender raptorial setae, and a pair of very long thin movable hooks; the teeth are almost obsolete, but the spinules which arm them remain. The abdomen is scarcely narrowed posteriorly before the ninth segment, so that the side margins seem to be continued posteriorly in the long spines of that segment. The superior appendage is one fourth, and the lateral appendages are one half shorter than the inferiors. Imagos and the two known species of nymphs may be separated by the following key.

### KEY TO SPECIES OF CELITHEMIS

*Imagos*

*a* Wings spotted with brown beyond the nodus

*b* Expanse of wings at least 65 mm; a band of brown on the wings at the nodus reaching almost across the wings.................... eponina

*bb* Expanse of wings not over 60 mm; a small rounded spot of brown just beyond the nodus ........................................ elisa

*aa* Wings with no brown markings except at base..................... ornata

*Nymphs*

*a* Unknown ................................................ ornata

*aa* Dorsal hooks well developed on abdominal segments 4 to 7, longest on segment 6 and sharp; lateral spines of the ninth segment reaching level of the apices of the inferior appendages; lateral setae eight or nine ................................................ eponina

*aaa* Dorsal hooks weakly developed on segments 5 to 7, short, but pointed; lateral spines of the ninth segment attaining only the level of the tip of the superior appendage; lateral setae seven.................. elisa

## Celithemis eponina Drury

Plate 24, fig. 2

1773 Libellula eponina Drury, Illus. exotic ins. v. 2, pl. 47, fig. 2

1861 Celithemis eponina Hagen, Synopsis Neur. N. Am. p. 147

1875 Celithemis eponina Hagen, Bost. soc. nat. hist. Proc. 18:66-67

1893 Celithemis eponina Calvert, Am. ent. soc. Trans. 20:261 (description)

1895-97 Celithemis eponina N. Y. ent. soc. Jour. 3:48 and 5:94 (listed from Westchester co. New York, Lake Bluff, Wayne co.)

1898 Celithemis eponina Needham, Outdoor studies, p. 60, fig. 60, (habits)

1899 Celithemis eponina Kellicott, Odon. Ohio, p. 103

1900 Celithemis eponina Williamson, Dragon flies Ind. p. 318

This beautiful skimmer is abroad about the latter end of June and the first weeks of July in our latitude. It frequents the borders of ponds and neighboring grassy slopes, and sometimes when foraging, it is carried far from water by the winds. Its flight is not the swiftest or the most continuous, and there is a flutter to it suggestive of the flight of a butterfly. So far as I have observed, the female in ovipositing is held by the male, and both are apt to be seen on windy days when other species are in shelter, dipping to the surfaces of foaming waves, far out from shore. The eggs are better distributed than in most related species, and, possibly for this reason, they seem to be somewhat fewer, and of larger size. Each egg is rotund oblong, whitish at first, soon turning yellowish.

**Nymph.** Total length 21 mm; abdomen 12.5 mm; hind femur 6 mm; width of head 6 mm, of abdomen 7 mm.

To the foregoing generic characterization of the nymphs of Celithemis and to the statement of the characters made for this species in the table, it need only be added here that in this nymph there is a blackish band between the eyes, and the femora are ringed with the same color; the abdomen is widest across the sixth segment, beyond which the sides seem scarcely narrowed to the tips of the lateral spines of the ninth segment; the lateral margins of segments 8 and 9 are conspicuously spinulose serrate.

The nymphs clamber about on submerged objects, and climb up stumps, etc., at the bank to transform, going but a little way, usually not farther than a foot.

## Celithemis elisa Hagen

1861 Diplax elisa Hagen, Synopsis Neur. N. Am. p. 182

1867 Diplax elisa Packard, Am. nat. 1:311, pl. 9, fig. 5

1862 Celithemis elisa Walsh, Acad. nat. sci. Phil. Proc. p. 400

1875 Celithemis elisa Hagen, Bost. soc. nat. hist. Proc. 18:67

1893 Celithemis elisa Calvert, Am. ent. soc. Trans. 20:261 (description)

1895 Celithemis elisa Walsh, N. Y. ent. soc. Jour. 3:48 (listed from Long Island, New York and Ithaca)

1899 Celithemis elisa Kellicott, Odon. Ohio, p. 104 (description)

1900 Celithemis elisa Williamson, Dragon flies Ind. p. 318 (description)

This species has about the same seasonal range as the preceding. E. B. Williamson has written (*loc. cit.* p. 319-20) very interestingly of the habits of the imago, as follows.

This species may often be found resting on the inflorescence of some of the rushes, preferably the bulrush, Scirpus lacustris, growing in the shallow waters of our lakes. So perched on a swinging rush, they have a wide view of what is going on about them and at the same time are inconspicuous, harmonizing well with the dingy brown of the over ripe flowers to which they cling. From this vantage ground they make sudden dashes at passing Diptera and smaller dragon flies, often returning to the identical sedge time and again. Each is the proprietor of a particular locality. When one encroaches on the hunting territory of another, he is quickly hustled away by the rightful and irate owner . . . The females are more retired, and are usually found among the sedges back from the water's edge.

**Nymph.** Measures in total length 14.5 mm; abdomen 8 mm; hind femur 4 mm; width of head 4 mm, of abdomen 5 mm. These measurements are taken from a rather small nymph skin, from New England—a bred specimen, and the only specimen in my possession. I should expect the typical elisa nymphs from localities farther west would be of somewhat larger size.

## ? Celithemis ornata Rambur

1842 Libellula ornata Rambur, Ins. Neur. p. 96
1861 Diplax ornata Hagen, Synopsis Neur. N. Am. p. 182
1861 Diplax amanda Hagen, Synopsis Neur. N. Am. p. 183
1893 Celithemis ornata Calvert, Am. ent. soc. Trans. 20: 261 (description)

Maine to Florida along the coast; not as yet recorded from this state. Nymph unknown.

### LEUCORHINIA

A single species, the common L. intacta, has been recorded hitherto from this state. A second species is now added, L. glacialis, which was common at Saranac Inn. I have bred, and describe below the nymphs of both these species, as well as the female imago of the latter species which has not hitherto been known.

Imagos of this genus flit about the vegetation of marshy shores, or go foraging along weedy roadsides near by. Their flight is not long sustained, consisting mainly of short sweeps from one resting place to another. The nymphs clamber among the submerged stems of aquatic plants. They are smooth, clean, and generally show a definite and well marked color pattern, of brown on a greenish ground, harmonizing well with the environment of mixed green and dead stems. They agree in having the eyes laterally prominent, but a little less so than in Celithemis, lacking the tendency toward the lateral angulation seen in that genus, in having a larger number of lateral setae on the labium (10–11), in having the abdomen a little narrowed beyond the sixth segment, and the dorsal hooks on segments 5-8 sharply bent posteriorly just above their bases, and long—as long as their respective segments—and very sharp.

Our two species may be separated by the following keys.

### KEY TO SPECIES OF LEUCORHINIA

*Imagos*

*a* Inferior appendage of the males bifurcated; generally, a yellow twin spot on the dorsum of the seventh abdominal segment; females with the two lobes of the vulvar lamina long and slender, each much longer than wide ..... intacta

*aa* Inferior abdominal appendage of the male not bifurcated, with only a shallow angular notch in its end, no twin spot on segment 7; vulvar lamina of the female with its two lobes little developed, much shorter than broad ..... glacialis

*Nymphs*

*a* Dorsal hook of the eighth abdominal segment directed straight posteriorly at its apex; lateral setae 10 ..... intacta

*aa* Dorsal hook of the eighth abdominal segment strongly declined at its tip; lateral setae 11 resting on the dorsum of the ninth segment..... glacialis

## **Leucorhinia intacta** Hagen

*White face*

1861 Diplax intacta Hagen, Synopsis Neur. N. Am. p. 179

1890 Leucorhinia intacta Calvert, Am. ent. soc. Trans. 18:39, pl. 5, fig. 1, 7–9

1890 Leucorhinia intacta Hagen, Am. ent. soc. Trans. 17:235, pl. 10, fig. 6, 8, 15, 16 and 23

1893 Leucorhinia intacta Calvert, Am. ent. soc. Trans. 20:262

1895–97 Leucorhinia intacta Calvert, N. Y. ent. soc. Jour. 3:48 and 5:94 (listed from Center, Keeseville, Ithaca, Westchester co., Croton on Hudson, Niagara river, etc.)

1899 Leucorhinia intacta Kellicott, Odon. Ohio, p. 106 (description)

1900 Leucorhinia intacta Williamson, Dragon flies Ind. p. 321 (description)

This species was not observed at Saranac Inn, but it is very common at Ithaca in the marshy flats below the city, at the head of Cayuga lake and in the shallow ponds between McLean and Freeville N. Y., where I have collected the nymphs in great numbers. I have observed the female imagos ovipositing in two quite different ways: descending and striking the water with the tip of the abdomen while in flight after the manner most common among Libellulidae, and at rest on some vertical stem at the surface of the water, plying with the tip of the abdomen just below the surface. In both cases the female was unattended by the male.

**Nymph.** Total length 17.5 mm; abdomen 10 mm; hind femur 5 mm; width of head 5 mm, of abdomen 6.5 mm.

In coloration the body shows generally very distinctly the following marks, besides others less distinct and constant. There is the usual black band across the head including the eyes, and the usual rings of brown are on the legs, and oblique stripes on the sides of the thorax; there is a pair of black bands emerging from beneath the tips of the wing cases, and extending to the sides of the 10th abdominal segment; there is a submedian, double row of round dots on the ventral side, running the length of the abdomen; and between these and the lateral margins of the abdomen there are two blackish, interrupted bands, one on each side.

The labium is ample, and has 10 lateral setae, and about 13 mental setae, of which the sixth (counting from the side) is longest; the teeth are obsolescent, but still distinctly crenate in form, and armed with several spinules each; the abdomen is widest across the sixth segment, narrowing slowly to the eighth segment, and then suddenly narrowed at the ninth; the lateral spines of the eighth segment surpass the middle of the ninth segment on its dorsal side; those of the ninth segment about attain the level of the tip of the superior appendage; the lateral appendages are half as long as the inferiors, and these exceed the superior a little; dorsal hook of the third segment very minute, erect; that of the fourth segment erect also but larger, the remaining hooks of more nearly equal size, laterally flattened, and above their bases strongly bent posteriorly, the tip of the hook of the eighth segment being scarcely more declined than the tip of the hook of the segment before it.

## **Leucorhinia glacialis** Hagen

Plate 10.

1890 Leucorhinia glacialis Hagen, Am. ent. soc. Trans. 17:234, pl 10, fig. 3 and 14

This species has been known hitherto from a few male specimens collected at Cape Breton, N. S., London, Ont.; Michipicoten on Lake Superior; Reno, Nev.; and in the White mountains of New Hampshire. It has not been recorded from New York state, but I found it common at Saranac Inn. During the first week or two of adult life, before age and pruinosity have obscured its remarkably fine coloration, it is a singularly beautiful insect. One who sees only preserved specimens would not suspect this however, for in such, faded browns have replaced the ruby red color of the males and the brilliant yellow of the females. I well remember with what delighted surprise I greeted my first specimen. It was a young male, with a brilliant red body phalerate with jet black, a flavescent tinge beyond the basal markings of the wings, a rich red-brown stigma, with a touch of yellow on the costa either side of it, and a face with the whiteness and subopaqueness of fine china. That specimen was captured beside the Inn road in the last week of June; soon afterward I found plenty of them—females as well—about the bog pond that lies near this road south of the station; they were flying with Cordulia shurtleffi, Dorocordulia libera, and Lestes eurina—a group of rare beauties.

Early in July I found them commonly about the outlet of Little Clear pond, and there obtained nymphs (which later were reared), saw the females ovipositing and obtained the eggs.

**Female imago** (hitherto undescribed; pl. 10, fig. 3). Length 34 mm; abdomen 23 mm; hind wing 25 mm.

Similar to the male, with only the middle half of the labium black, the sides white (I have a small male that is so, also); face opaque white. Thorax and basal segments of the abdomen brilliant yellow in life, phalerate with black; the middorsal thoracic stripe of black constricted above, dilated below; a short, not very distinct, isolated humeral stripe of black; complete stripes that are broad and irregular on the humeral and third lateral sutures, and an oblique lateral stripe crossing the midlateral suture and joining the humeral stripe; a black mark on the mesothoracic spiracle; dorsal and lateral yellow areas almost enveloping the basal abdominal segments, but isolated on the first and second segments, fused on the third, which is all yellow except an apical ring and a mark at each side below; there is a yellow dorsal mark on the fourth segment, and there are dorsal yellow triangles on segments 5–7; there is also a lateral yellow basal triangle on each side of the fourth segment. The wings have the basal marking and the yellow

points at the ends of the stigma as in the male, but they are more flavescent in their basal half. The vulvar lamina is very short, being very much broader than long, with a quadrangular excavation in the middle separating its two low lobes widely; far beyond the apices of these two lobes and near the middle of the venter of the ninth segment there is a pair of minute, erect quadrangular prominences; the apical margin of the venter of the ninth segment is very convex.

I observe in my specimens considerable variation in the size of the males: 32 to 37 mm in length; the genitalia, however, are quite constant in form and agree well with the figures by Hagen cited above.

**Nymph.** (Pl. 10, fig. 1, 2) Total length 18 mm; abdomen 10 mm; hind femur 5.5 mm; width of head 5.5 mm, of abdomen 6.7 mm.

Unfortunately, I obtained but few nymphs, and reared them all, so that I have nothing left but the cast skins for description; these do not preserve well the nymphal color pattern when dry; there is enough of it left to show that the coloration is similar to that of L. intacta described above, though probably not so well marked. The nymph is so very similar to the preceding, it is hardly worth while to repeat the description in detail. The more salient points are as follows. The lateral setae are 11; the mental setae about 13, of which the sixth (counting from the side) is longest; the lateral spines of the eighth abdominal segment are a trifle longer than half the dorsal length of the ninth segment, the lateral spines of the ninth segment attain to the level of the tips of the inferior appendages, which are scarcely longer than the superior appendage. The dorsal hooks are as described above for L. intacta; excepting that the apex of the hook of the eighth segment is declined so that it rests at its apex on the dorsum of the ninth segment.

This last and most distinctive character between the two species is shown by some nymphs which were collected for me by Chester Young at Ellenville N. Y., May 30, 1897. These, from the Catskills, may be the nymphs of L. glacialis also; but, among so many species so much alike, and so few of them bred, they can not be so determined with certainty as yet.

The eggs are roundish oval, with a moderate investment of gelatin. They are white at first, but turn a pale lemon yellow after a number of hours. They are dropped by the female in flight in the little clear pools along shore, strewn over the bottom with hemlock leaves.

### SYMPETRUM

This large genus is represented in New York state by seven nominal species, and an eighth is regional. Most of these species are exceedingly common along marshy shores and in wet meadows. The imagos travel often considerable distances from the water, and at the proper season are met with on upland meadows very commonly. Because of their familiar habits and their strikingly brilliant red coloration, they are very well known.

The nymphs are very like those of Leucorhinia, specially the species placed first in our list; but they are (except S. corruptum)

of smaller size and have the dorsal hooks of the abdomen less developed. The following keys will serve for the separation of our imagos and also of the nymphs as far as I have been able to find any differences between them.

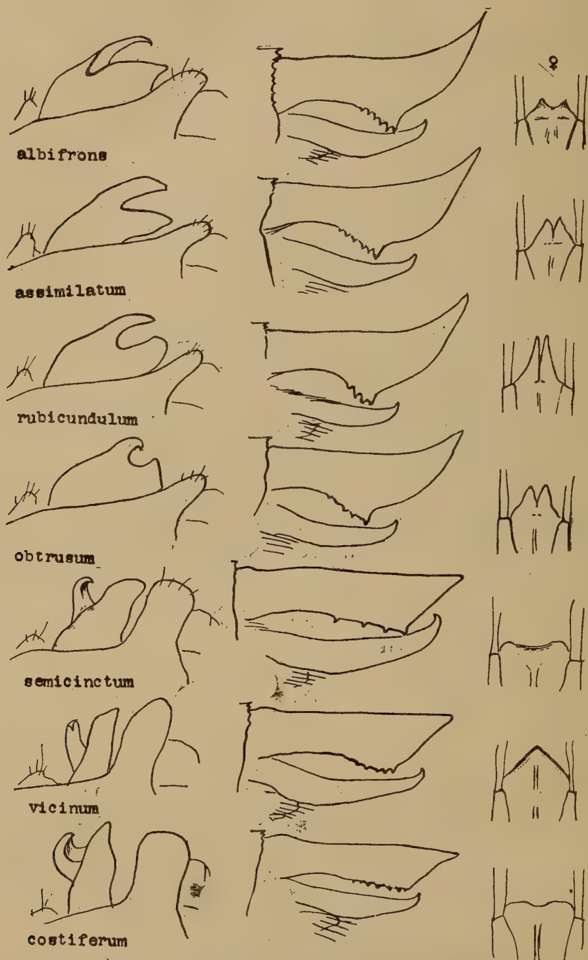


Fig. 30 Genitalia of the New York species of Sympetrum (excepting S. corruptum Hagen); first column, external view of the male genital hamule; second column, lateral view of male abdominal appendages; and third column, ventral view of vulvar lamina of the female, for the species named in the figure

## KEY TO SPECIES OF SYMPETRUM

### *Imagos*

*a* With a median transverse ridge incircling the fourth abdominal segment (in addition to the normal apical ridge) .............................. corruptum

*aa* With no such added ridge on the fourth abdominal segment

*b* Superior appendages of the male with a prominent median inferior tooth, having some denticles before it; vulvar lamina of the female divided by a median cleft into two pointed lobes

*c* Tibiae and tarsi yellow externally; the black of the abdominal segments tending to form apical rings .............................. albifrons

*cc* Tibiae and tarsi wholly black; the black of the abdominal tending to form apical lateral triangles

*d* Wings with the basal half (or somewhat less) flavescent; branches of the genital hamule of the male inclosing an angular notch; vulvar lamina of the female with its lobes short and sharply recurved upward, their apices meeting the venter of the ninth segment vertically assimilatum

*dd* Wings flavescent only at the extreme base; branches of the genital hamule of the male inclosing an oval or a rounded notch; vulvar lamina of the female with appressed lobes which meet the venter of the ninth segment more obliquely

*e* Branches of the genital hamule of the male inclosing an oval notch, the outer about twice as stout as the inner, about equally curved; the vulvar lamina of the female with its sides regularly sloping rubicundulum

*ee* Branches of the genital hamule of the male inclosing a short rounded notch, the inner branch more sharply incurved, the outer about four times as thick as the inner; the vulvar lamina of the female somewhat contracted at about midway its length, the sides more convergent in the basal half.............................. obtrusum

*bb* Superior abdominal appendage of the male without a prominent inferior median tooth, but only with small inferior denticles of about equal size; vulvar lamina of the female not cleft

*c* Wings with the basal half flavescent.................... semicinctum

*cc* Wings flavescent only at the extreme base

*d* Femora and tibiae entirely yellow .......................... vicinum

*dd* Femora and tibiae marked with black on the sides...... costiferum

## *Nymphs*[1]

*a* Dorsal hooks of abdominal segments 6–8 long and sharp, about as long as their respective segments

*b* Lateral spines straight on both outer and inner margins.... costiferum

1 The nymphs of albifrons and corruptum are unknown; that of the former species is likely to be of the type of the nymph of rubicundulum. I give a figure (pl. 25, fig. 1) of a nymph from southern California of S. illotum, the nearest ally of corruptum. The nymph of corruptum will probably be of this type.

I have nymphs of rubicundulum raised at Ithaca, of obtrusum, raised at Lake Forest Ill., and of assimilatum raised at Saranac Inn. Between the nymphs of rubicundulum and obtrusum I find only a scarcely perceptible difference in size, that of obtrusum being a little smaller, in the bred specimens. Both these are a very little smaller than assimilatum; and I note that in the bred specimens the dorsal hooks on the fourth and fifth abdominal segments (hidden between the wing cases) are larger and more nearly equal in size in assimilatum, smaller and more unequal in size and paler in the other two. These differences are so slight and have been studied in so few specimens that I have not thought best to introduce them as yet into the table.

As to the imagos of these three nominal species, I know of no absolutely constant differences either in size, coloration, structure, distribution or habits that will in every case distinguish between them. The typical rubicundulum is of course, intermediate between the other two. I have examined hundreds of specimens of each, and say unhesitatingly that they intergrade completely; nevertheless, it is convenient to recognize the three forms, and practically, there is little difficulty generally in distinguishing between them. I have therefore listed them separately.

*bb* Lateral spines of the ninth segment straight on the inner, but incurvate on their outer margins

*c* Lateral spines of the eighth segment thin, flat and sharp, attaining the level of the apical margin of the ninth segment on the middorsal line ........ vicinum

*cc* Lateral spines of the eighth segment stouter, their tips hardly surpassing the middle of the dorsum of the ninth segment........ semicintum

*aa* Dorsal hooks of abdominal segments 6-8 shorter than the segments bearing them, and less pointed. assimilatum, rubicundulum, obtrusum

## **Sympetrum costiferum** Hagen

Figure 30

1861 Diplax costifera Hagen, Synopsis Neur. N. Am. p. 175

1895 Diplax costifera Calvert, N. Y. ent. soc. Jour. 3:48 (listed from Amherst)

This species came up quite unexpectedly in one of my breeding cages at Saranac Inn. I had collected a number of nymphs from the shore of Little Clear pond near the outlet, and put them in this cage, supposing them to be of one species; they yielded at transformation imagos of S. vicinum, but one nymph yielded a fine male specimen of this species. It is the one from which the characters stated herewith are drawn. No imagos were seen at large. This one appeared on August 8. The cast skin was left in a somewhat collapsed condition, so that it is hard to measure accurately; but the measurements are, as nearly as I can make out, as follows: total length 14.5 mm; abdomen, 9 mm; hind femur 5 mm; width of head 5 mm, of abdomen, 6 mm.

The eyes are a trifle less prominent than in S. vicinum; there are 11 lateral setae, and about 13 mental setae, of which the fifth, counting from the side, is longest, the movable hook is somewhat shorter and thicker than in S. vicinum, and the teeth are more nearly obsolete; the lateral spines of the eighth abdominal segment are about half as long as is that segment; those of the ninth segment are much longer, slender, straight on both margins, and their tips scarcely attain the level of the tips of the appendages. The superior appendage is scarcely shorter than the inferiors, but these laterally are less than one half as long.

## **Sympetrum vicinum** Hagen

Figure 30

1861 Diplax vicina Hagen, Synopsis Neur. N. Am. p. 175

1893 Diplax vicina Calvert, Am. ent. soc. Trans. 20:264 (description and figure)

1895–97 Diplax vicina Calvert, N. Y. ent. soc. Jour. 3:48 and 5:94 (listed from Lake St Regis, Keeseville, Dobbs Ferry, New York, Ithaca, Catskill mountains, Schoharie, Piseco lake and Buffalo)
1899 Diplax vicina Kellicott, Odon. Ohio, p. 110 (description and figure)
1900 Diplax vicina Williamson, Dragon flies Ind. p. 323

This pretty, little, yellow-legged, autumnal species is likely to be found about every marsh-bordered pond in the state. It flits about the shore vegetation and is not at all difficult to capture with a net. At Cascadilla pond near Ithaca I have watched the females ovipositing on beds of wet and matted dwarf club-rush, sometimes alone, but oftener held by the male, both descending together and rising every time the tip of the abdomen was brushed against the wet mats. Some eggs obtained in September at Ithaca hatched the following January, having been kept the while in a laboratory of the normal temperature. Doubtless, under normal conditions they do not hatch before spring.

**Nymph.** Total length 13 mm; abdomen 8 mm; hind femur 4.5 mm; width of head 4.5 mm, of abdomen 5 mm.

The eyes are a little more prominent laterally than in other members of the genus; the lateral setae are nine; mental setae about 12 or 13, the fifth (counting from the side) longest; the movable hook is excessively long and slender; the superior appendage is one third shorter than the inferiors, and the laterals less than one half as long as the inferiors.

At Saranac Inn, the nymphs were found at the north side of the outlet of Little Clear pond, on the shelving bank behind the hummock of cattails. They are rather daintily colored with bands of black across the head, including the eyes, around the femora, and across the middle of the abdominal segments. They clamber about amid the semiaquatic vegetation.

## Sympetrum semicinctum Say

Figure 30

1839 Libellula semicincta Say, Acad. nat. sci. Phil. Jour. 8:27
1861 Diplax semicincta Hagen, Synopsis Neur. N. Am. p. 176
1893 Diplax semicincta Calvert, Am. ent. soc. Trans. 20:263 (description and figure)
1895 Diplax semicincta Calvert, N. Y. ent. soc. Jour. 3:48 (listed from Ithaca, Staten Island, Westchester co.)
1899 Diplax semicincta Kellicott, Odon. Ohio, p. 110 (description and figure)
1900 Sympetrum semicinctum Williamson, Dragon flies Ind. p. 324 (description and figure)

This species, which I have observed at Ithaca, and have bred in Illinois, did not appear at Saranac Inn. It is quite like the others of the genus. I have observed the female ovipositing alone in muddy pools among dead smartweed stems on a mud flat beside a pond.

**Nymph.** (Pl. 25, fig. 2) Of much the same form as that of S. vicinum, but a little larger (at the time of writing this I have not my specimens at hand for reference, and can not therefore give the exact measurements; I have all the other details carefully recorded in note and drawings, but the measurements have been accidentally omitted); the eyes are laterally prominent, but well rounded; lateral setae nine; mental setae about 12, of which the fifth (counting from the side) is longest; the dorsal hooks on the fourth and fifth abdominal segments are less than one third as large as those on the three following segments; the superior abdominal appendage is one fourth shorter and the laterals are one half shorter than the inferiors; the spines of the ninth segment surpass the apices of the superior appendage, and are strongly incurved, and spinulose serrate on their exterior margins.

## **Sympetrum assimilatum** Uhler

Figure 30

1857 Libellula assimilata Uhler, Acad. nat. sci. Phil. Proc. p. 88

1893 Diplax rubicundula var. assimilata Calvert, Am. ent. soc. Trans. 20 : 263

1899 Diplax rubicundula Kellicott, Odon. Ohio, p. 109 (description)

This was very common at Saranac Inn in Little Clear creek. During the latter part of July the nymph could be seen any clear morning climbing up the Sparganium stems, and transforming. The nymphs were obtained whenever collecting was done from the beds of standing vegetation along the creek.

## **Sympetrum rubicundulum** Say

Figure 30

1839 Libellula rubicundula Say, Acad. nat. sci. Phil. Jour. 8 : 26

1861 Diplax rubicundula Hagen, Synopsis Neur. N. Am. p. 176

1866 Diplax rubicundula Scudder, Bost. soc. nat. hist. Proc. 10 : 219

1893 Diplax rubicundula Calvert, Am. ent. soc. Trans. 20: 262 (description)

1899 Diplax rubicundula Kellicott, Odon. Ohio, p. 109 (description)

1900 Diplax rubicundula Williamson, Dragon flies Ind. p. 322 (description)

Pale, teneral, yellowish specimens of this species begin fluttering up out of the grasses that fill the shallow water in the upper reaches of most ponds about the latter end of June. A month later, when they have assumed their brillant black and red coloration, and have become more numerous, we find them scattered everywhere. They seem most numerous, however, about wet meadows, where they delight to go foraging.

The nymph, like that of the preceding and that of the following species (the only differences that I have observed between these I have already stated in a footnote to the nymph table) has nine lateral setae, and 12 mentals, of which the fifth (counting from the side) is longest; the dorsal hooks on segments 4–8 are low, less considerable in length than the segments which bear them, but sharp; the lateral spines of the eighth and ninth segments are less developed, and follow in their external contour the incurvate lines of the posteriorly narrowing abdomen; the lateral appendages are half as long as the inferiors, which are distinctly longer then the superior.

### **Sympetrum obtrusum** Hagen

Figure 30

1867 Diplax obtrusa Hagen, Stett. ent. zeit. 28:95
1893 Diplax obtrusa Calvert, Am. ent. soc. Trans. 20:264 (description and figure)
1899 Diplax obtrusa Kellicott, Odon. Ohio, p. 109 (description and figure)
1900 Diplax obtrusa Williamson, Dragon flies Ind. p. 323 (description)

For this and the two foregoing species I have hardly thought it worth while to state the distribution in detail, it is so general throughout the state, whenever any collecting has been done.

### **Sympetrum albifrons** Charpentier

Figure 30

1841 Libellula albifrons Charpentier, Lib. Europ. p. 81, pl. 11, fig. 3
1861 Diplax albifrons Hagen, Synopsis Neur. N. Am. p. 177
1900 Sympetrum albifrons Williamson, Dragon flies Ind. p. 323 (description)

Not yet found in the state; nymph unknown.

### **Sympetrum corruptum** Hagen

1861 Mesothemis corrupta Hagen, Synopsis Neur. N. Am. p. 171
1893 Diplax corrupta Calvert, Am. ent. soc. Trans. 20:264 (description)
1897 Diplax corrupta Calvert, N. Y. ent. soc. Jour. 5:95 (listed from Staten Island)
1897 Diplax corrupta Van Duzee, N. Y. ent. soc. Jour. 5:91 (listed from Lake Erie)
1899 Diplax corrupta Kellicott, Odon. Ohio, p. 111 (description)
1900 Diplax corrupta Williamson, Dragon flies Ind. p. 324 (description)

This species is much more common westward; its nymph is unknown.

## PACHYDIPLAX

There is a single species.

### Pachydiplax longipennis Burmeister

1839 Libellula longipennis Burmeister, Handb. ent. 2:850

1861 Mesothemis longipennis Hagen, Synopsis Neur. N. Am. p. 173

1893 Pachydiplax longipennis Calvert, Am. ent. soc. Trans. 20:265

1895–97 Pachydiplax longipennis Calvert, N. Y. ent. soc. Jour. 3:48 and 5:94 (listed from New York, Westchester co., Ithaca and Blackrock)

1899 Pachydiplax longipennis Kellicott, Odon. Ohio, p. 114 (description)

1900 Pachydiplax longipennis Williamson, Dragon flies Ind. p. 326 (description)

This is a species of very wide distribution. It has been recorded from most regions of North America, south of the Canadian, from Mexico, and from the Bahama islands, and last summer Dr O. S. Westcott, stopping to visit our station on his return from the Bermuda islands, brought a number of specimens collected in that new quarter. The species was not observed at large at Saranac Inn. It is likely to be found rather generally distributed throughout the state at lower altitudes.

Imagos of this species are swift of wing, and somewhat difficult to capture with a net. The males hover near the surface of the water, darting hither and thither, meeting every newcomer, perching on a twig and immediately quitting it; and, when two males meet in combat, they have the curious habit of darting upward together into the air and flying skyward, often, till lost from view. The females are less in evidence. They rest habitually, except when foraging or ovipositing on trees back from the shore. When ovipositing over open water, they have a curious habit which I have not observed in other dragon flies: they do not rise and descend again between strokes of the end of the abdomen against the surface of the water, but fly along horizontally close to the surface and from time to time strike downward with the abdomen alone, presumably washing off the eggs. In the midst of vegetation, however, they fly down and up again, as do other species.

The nymphs clamber about among the trash, and, when grown, transform within a few inches of the margin of the water, if suitable place be found so near; otherwise they may go a distance of several feet. They are smooth, generally of dark color, with little pattern of color showing, except in the transverse banding of the femora.

**Nymph.** Total length 21 mm; abdomen 12 mm; hind femur 6 mm; width of head 6 mm, of abdomen 7.5 mm.

Easily recognizable among other libelluline nymphs (when well grown at least) by the head twice as wide as long, the entire absence of dorsal hooks, the smooth and depressed body, and by the superior appendage being one third shorter than the inferiors and twice as long as the laterals. The labium is large, and the median lobe is at its maximum size; hook long and slender; laterals 10; mentals about 12, the fifth or sixth (counting from the side) longest; the lateral spines of the eighth and ninth segments of the abdomen are very similar in size and shape, those of the ninth segment extending posteriorly almost to the level of the tips of the inferior appendages.

### MESOTHEMIS

There is a single species occurring within the state.

### **Mesothemis simplicicollis** Say

1839 Libellula simplicicollis Say, Acad. nat. sci. Phil. Jour. 8:28

1861 Mesothemis simplicicollis Hagen, Synopsis Neur. N. Am. p. 170

1893 Mesothemis simplicicollis Calvert, Am. ent. soc. Trans. 20:265 (description)

1895–97 Mesothemis simplicicollis Calvert, N. Y. ent. soc. Jour. 3:48 and 5:94 (listed from New York, Westchester co., Ithaca and Towanda creek)

1899 Mesothemis simplicicollis, Kellicott, Odon. Ohio, p. 113 (description)

1900 Mesothemis simplicicollis, Williamson, Dragon flies Ind. p. 325

This is another species of wide distribution, that is much more common southward and westward: a single specimen was seen at Saranac Inn. I remember having seen but very few at Ithaca. I bred this species and P. longipennis in Illinois in 1895. The imagos of this species have more of the gomphine habit of squatting on the ground than any other libellulines known to me. That may be the meaning of the long spines on the hind femora. They do not seek the topmost twigs of reeds, as do most other shore-frequenting species, but settle by preference in some bare path, or aslant a board at the edge of the water. The nymphs are rapid climbers among reed stems. In life their eyes are yellowish externally, and the teeth on the edges of the labial lobes are white. The bodies of the nymphs are greenish with little pattern showing.

**Nymph.** Measures in total length 17 mm; abdomen 9 mm; hind femur 5 mm; width of head 5 mm, of abdomen 5.5 mm.

It is recognizable at a glance among all other libelluline nymphs known to me by the thickness of the body, the bulging prominence of the eyes, the relative brevity of the abdomen, and the decurved appendages at the apex of the abdomen.

The median labial lobe is very prominent; the teeth on the edges of the lateral lobes are obsolete; the lateral setae are eight, and of these the proximal one is a small one; the mental setae are about 13, of which the eight outermost are a series of larger size. There are no dorsal hooks, but there are some coarse hairs on the transverse apical carinae of the segments, and there is a long brush of these springing from the apical ventral margin of the ninth segment; there are no lateral spines, or the merest vestiges of them remain sometimes on the ninth segment: the appendages are all decurved, the inferiors most strongly; the superior is a little shorter than the inferiors, a little longer than the laterals; the prothoracic spiracles are elevated to the highest point of the body. So unique are a number of these characters, there is no confusing this nymph with the others of the subfamily.

### MICRATHYRIA

A single species of our fauna is referred to this genus.

## **Micrathyria berenice** Drury

1773 Libellula berenice Drury, Illus. exotic ent. v. 1, pl. 48, fig. 3

1839 Libellula berenice Say, Acad. nat. sci. Phil. Jour. 8:25

1861 Diplax berenice Hagen, Synopsis Neur. N. Am. p. 178

1867 Diplax berenice Packard, Am. nat. 1:311, pl. 9, fig. 3 and 4

1893 Micrathyria berenice Calvert, Am. ent. soc. Trans. 20 : 260 (description)

1895–97 Micrathyria berenice Calvert, N. Y. ent. soc. Jour. 3:47 and 5; 94 (listed from Thousand Islands, New York and Sheepshead bay, L. I.)

This is a species I have never seen alive. It is said to be common down the valley of the Hudson. Its nymph is unknown.

### LADONA

Of the three forms comprising this genus, originally described as distinct species, two probably occur within the limits of New York state. In what I have written concerning these hitherto, I have followed without question the synonymy as given by Hagen and Calvert, according to which both deplanata of Rambur and julia of Uhler are but varieties of exusta Say, not even bearing a varietal name. A. P. Morse has called my attention to some facts which seem to indicate that these three may yet have to be considered as distinct species. I may add that my breedings have furnished farther facts corroborating this opinion.

Before the "lumping" process began the bibliography of these forms was as follows.

1839 Libellula exusta Say, Acad. nat. sci. Phil. Jour. 8:29

1842 Libellula deplanata Rambur, Ins. Neur. p. 75

1857 Libellula julia Uhler, Acad. nat. sci. Phil. Proc. p. 88

Then Hagen, in his *Synopsis of the Neuroptera of North America* (1861), ranked deplanata and exusta as synonymous (under the later name, however); in his *Synopsis of the Odonata of America* (1875) he ranked them separately, remarking that deplanata was probably but a dwarf southern form of exusta, but he wrote down julia as a synonym of exusta. In 1893 Calvert in his *Odonata of Philadelphia and vicinity* again added deplanata to the exusta lump. The three have been treated as one ever since, and in all recent descriptions and lists, dimensions, coloration, structural characters and distribution are hopelessly confused; and it becomes necessary to revert to the original descriptions to find statement of differences between them.

The two which concern us here in New York are L. exusta Say and L. julia Uhler. So far as I am able to judge by my own specimens and by those in the Museum of comparative zoology at Cambridge, these seem to be distinguished by the following characters.

*a* Dorsum of the thorax pale with a black stripe each side on the humeral suture, no ante-humeral stripe of white; the fuscous spot on the base of the hind wing not enveloping the triangle; the eighth abdominal segment of the male narrower than the seventh; the apex of the anterior branch of the genital hamule of the male directed laterally ........ julia

*aa* Dorsum of the thorax blackish brown, with a white ante-humeral stripe each side; the fuscous spot of the hind wing envelops the triangle; the eighth abdominal segment in the male is as wide as or wider than the seventh; the apex of the anterior branch of the genital hamule of the male is directed posteriorly.............................................. exusta

I have described in the *Canadian entomologist* for 1897 (29: 144–46) the nymphs of deplanata from Florida. These differ from the nymphs of L. julia described below by some unusually good specific characters, such as the entire absence of raptorial setae from the median lobe of the labium, and the hooked teeth on the margin of the lateral lobes. It remains now to discover the nymph of exusta, and to learn whether deplanata agrees with it.

Fig. 31 Male genital hamules of Ladona julia Uhl. (*u*) and L. exusta Say (*v*)

It will be observed that the characters given in the generic table for nymphs at the beginning of this subfamily abundantly justify the erection of Ladona as a genus separate from Libellula.

L. exusta is recorded in Calvert's list of the Odonata of New York state from Lake George, and Croton on Hudson. Whether the record be for exusta or for julia, is uncertain. The characters given above will I trust, enable the collector in the future to distinguish between these

two; and if some collector find the typical *exusta* to be common, he may aid the farther solution of this question by setting about to find its nymph. I discuss below the single form which I have found within the state.

### Ladona julia Uhler

1857 *Libellula julia* Uhler, Acad. nat. sci. Phil. Proc. p. 88
1861 *Libellula julia* Hagen, Synopsis Neur. N. Am. p. 153
1867 *Libellula julia* Hagen, Stett. ent. zeit. 28:192

This species was very common at Saranac Inn. It was beginning to appear in numbers on the wing at the time of our arrival, June 13. I went out to the banks of Little Clear pond at sunrise of the morning of the 14th and found a number of nymphs transforming, associated with *Tetragoneuria*. The imagos were abundant along every roadside during the month of June, and females were only a little less in evidence than the males. Nymphs were taken abundantly from the trashy places in the borders of Little Clear and Bone ponds, and a few were found in Little Clear creek; exuviae were seen in numbers clinging to the banks of Colby pond, and a few along Stony brook near Axton.

**Nymph.** Total length 24 mm; abdomen 15.5 mm; hind femur 5.5 mm; width of head 5 mm, of abdomen 5.5 mm.

Body slender, elongate, moderately hairy, dark colored, without distinct pattern, but paler on the sutures and below.

Head somewhat wider than long, with eyes not very prominent, and hind margin slightly concave; median lobe of the labium with a median flat, toothlike prominence in the middle of its free border, on either side of which the border is crenulate, with spinules inserted singly in the notches between the crenulations; lateral setae six; hook slender, and not very long; mental setae three each side.

Abdomen with sharp lateral spines, relatively shorter than on the nymph of *deplanata*; dorsal hooks on segments 4–8 straight and sharp; superior and inferior appendages of about equal length, and about as long as the last two abdominal segments; lateral appendages one fifth to one fourth as long as the others.

The presence of three mental setae on the labium will distinguish this species at a glance from the nymph of *L. deplanata* of the south.

## LIBELLULA

This genus contains the species which are, perhaps, the best known of all our dragon flies. The imagos hover habitually over ponds in summer, are large, and for the most part beautifully colored, and are everywhere common. Eight species are known from the state, and it is not likely that any others will be found resident in numbers. It is of course always possible for a few strays to be blown into new territory from distant regions by high winds. The nymphs of five of these eight species are

known, and are described and distinguished below. So much alike are they that a general account of the nymphal characters will save much restatement.

The known nymphs of this genus agree in having the body elongate, tapering to the pointed apex of the abdomen, hairy, the hairs serving to hold an ambuscade of silt about the body. Head compact, little wider than long, with the eyes capping the anterolateral angles, and directed anteriorly; head little narrowed behind the eyes; labium large, reaching posteriorly between the bases of the middle legs; median lobe with its front border not crenate; mental setae always present, variable in number; lateral setae five to nine; prothorax with a flatish dorsal shield, whose margins are generally fringed with coarse hairs; wing cases reaching the base of the sixth abdominal segment; abdomen triquetral, its lateral margins becoming acute posteriorly, with short lateral spines on segments 8 and 9; a variable number of dorsal hooks beginning on the third or fourth segment, sometimes quite rudimentary; ninth segment two to three times as long as the 10th; lateral appendages half as long as the others; tarsi with the second and third joints successively each a very little longer than the first.

The imagos discussed below, and the known nymphs of the same species may be separated by the following keys.

### KEY TO SPECIES OF LIBELLULA

#### *Imagos*

*a* Wings with no spot at the nodus
- *b* With a broad basal band of black covering the basal third of both wings ... basalis
- *bb* With the black color of the base of the wings confined to a narrow streak in the subcostal space, or entirely wanting
  - *c* Stigma bicolored
    - *d* Inner half of stigma white or yellow, outer half dark brown. cyanea
    - *dd* Stigma mainly yellow, but distinctly darker at the outer end ... plumbea
  - *cc* Stigma not differing in color at its inner and outer ends
    - *d* Stigma red or yellow; wings flavescent, unspotted.... auripennis
    - *dd* Stigma black ........................................ incesta

*aa* Wings with a small nodal spot which is restricted to the outer (distal) side of the nodus
- *b* With a large triangular patch of black extending from the triangle to the hind margin ........................................ quadrimaculata
- *bb* Without a black patch between the triangle and the hind margin in the hind wing ........................................ vibrans

*aaa* With a large nodal spot which completely surrounds the nodus
- *b* Nodal and apical wing spots yellowish or reddish....... semifasciata
- *bb* Nodal and apical wing spots blackish........................ pulchella

*Nymphs*

*a* Dorsal hooks on the seventh and eighth abdominal segments long and sharp
  *b* Lateral setae five........................................ auripennis
  *bb* Lateral setae six........................................ cyanea
  *bbb* Lateral setae seven........................................ basalis
*aa* Dorsal hooks on the seventh and eighth abdominal segments rudimentary (and hidden among scurfy hairs) or wanting
  *b* Lateral setae seven........................................ quadrimaculata
  *bb* Lateral setae eight to nine........................................ pulchella
*aaa* Nymphs unknown
axillena, plumbea, incesta and semifasciata

## **Libellula basalis** Say

1839 Libellula basalis Say, Acad. nat. sci. Phil. Jour. 8:23
1839 Libellula luctuosa Burmeister, Handb. ent. 2:861
1861 Libellula luctuosa Hagen, Synopsis Neur. N. Am. p. 152
1875 Libellula basalis Hagen, Bost. soc. nat. hist. Proc. 18:70
1893 Libellula basalis Calvert, Am. ent. soc. Trans. 20:255 (description)
1895-97 Libellula basalis Calvert, N. Y. ent. soc. Jour. 3:47 and 5:94 (listed from Dobbs Ferry, Ithaca, Kenwood, Niagara river)
1899 Libellula basalis Kellicott, Odon. Ohio, p. 96 (description)
1900 Libellula basalis Williamson, Dragon flies Ind. p. 329

This is not one of the more common species apparently in New York state. I have taken a few specimens at Ithaca; I saw one imago at Saranac Inn, and took one nymph there. I studied and reared the species in 1895 at Galesburg Ill., where it is abundant. Of a June morning half an hour after sunrise, I have seen scores of the nymphs transforming at a time on the blue-grass bordered banks of a little pond.

**Nymph.** Total length 25 mm; abdomen, 14 mm; hind femur 5.5 mm; width of head, 5.5 mm, of abdomen, 6.5 mm.

The points which will chiefly serve for comparison with other species are as follows: body not very hairy, generally dirty and showing little color pattern; lateral setae, seven; mental setae about 10 or 11, the outer five or six in a longer series; movable hook, long, slender, little curved; dorsal hooks on abdominal segments 4-8 all sharp and well exposed, but the sixth longest.

## **Libellula auripennis** Burmeister

*Golden-wing*

1839 Libellula auripennis Burmeister, Handb. ent. 2:861
1861 Libellula auripennis Hagen, Synopsis Neur. N. Am. p. 155
1866 Libellula auripennis Scudder, Bost. soc. nat. hist. Proc. 10:191
1893 Libellula auripennis Calvert, Am. ent. soc. Trans. 20:256 (description)

1895 Libellula auripennis N. Y. ent. soc. Jour. 3:47 (listed from the vicinity of New York)

1899 Libellula auripennis Kellicott, Odon. Ohio, p. 97 (description)

1900 Libellula auripennis Williamson, Dragon flies Ind. p. 329 (description)

This beautiful, golden-winged, southern species is not likely to be found in the state except near the coast. A few years ago Prof. A. L. Quaintance reared the species at Lake City Fla., and very kindly sent me the bred specimen with its cast skin, and some nymphs in alcohol. I have several times since received the nymphs from other localities in the south. I have not seen the species at large.

**Nymph.** Total length 27 mm; abdomen 17.3 mm; hind femur 6 mm; width of head 6 mm, of abdomen 7 mm.

The body is a trifle heavier than in the nymph of basalis and more hairy; the median lobe of the labium is decidedly pointed in the middle of its front border; lateral setae five; mental setae eight to ten, the six outer ones forming a larger series; movable hook rather stout and little curved; ninth abdominal segment twice as long on the ventral as on the dorsal side, twice as long above as the 10th segment; dorsal hooks on segments 3 or 4–8, straight, and sharp; appendages as long as the two last abdominal segments, the laterals half as long as the others.

## **Libellula vibrans** Fabricius

1793 Libellula vibrans Fabricius, Ent. syst. 2:380

1861 Libellula lydia Hagen, Synopsis Neur. N. Am. p. 155

1893 Libellula axillena vibrans Calvert, Am. ent. soc. Trans. 20:257

1895 Libellula axillena vibrans Calvert, N. Y. ent. soc. Jour. 3:47 (listed from Staten Island and Westchester co.)

1899 Libellula vibrans Kellicott, Odon. Ohio, p. 98 (description)

1900 Libellula vibrans Williamson, Dragon flies Ind. p. 330 (description)

Another handsome, graceful, well proportioned insect, of very swift flight; apparently not common in this state. Its nymph is unknown.

## **Libellula incesta** Hagen

1861 Libellula incesta Hagen, Synopsis Neur. N. Am. p. 155

1893 Libellula axillena incesta Calvert, Am. ent. soc. Trans. 20:257

1899 Libellula incesta Kellicott, Odon. Ohio, p. 99 (description)

1900 Libellula incesta Williamson, Dragon flies Ind. p. 330

This species has not as yet been taken in the state: it is almost sure to be found there eventually. It ranges from New Hampshire to Texas, and is said to be common in places in Ohio. Its nymph is unknown.

### Libellula plumbea Uhler

1857 Libellula plumbea Uhler, Acad. nat. sci. Phil. Proc. p. 87

1861 Libellula plumbea Hagen, Synopsis Neur. N. Am. p. 157

1893 Libellula plumbea Calvert, Am. ent. soc. Trans. 20: 256 (description)

1895 Libellula plumbea Calvert, N. Y. ent. soc. Jour. 3: 47 (listed from Westchester co.)

This is another southern species which seems not likely to be found commonly in the state excepting possibly in the lower valley of the Hudson river. Its nymph is unknown.

### Libellula cyanea Fabricius

1775 Libellula cyanea Fabricius, Syst. ent. p. 424

1839 Libellula quadrupla Say, Acad. nat. sci. Phil. Jour. 8: 23

1857 Libellula bistigma Uhler, Acad. nat. sci. Phil. Proc. p. 87

1861 Libellula quadrupla Hagen, Synopsis Neur. N. Am. p. 157

1893 Libellula cyanea Calvert, Am. ent. soc. Trans. 20: 556 (description)

1895 Libellula cyanea Calvert, N. Y. ent. soc. Jour. 3: 47 (listed from the vicinity of New York)

1899 Libellula cyanea Kellicott, Odon. Ohio, p. 97 (description)

1900 Libellula cyanea Williamson, Dragon flies Ind. p. 330.

This species ranges from Massachusetts to Indiana and South Carolina; it is likely to be found eventually in numerous unreported localities in New York state. I have not seen it at large, but I have been allowed to study a bred specimen kindly lent me by Samuel Henshaw, and from that specimen, the following characters of the nymph are drawn.

**Nymph.** Total length 20 mm; abdomen 13.5 mm; hind femur 5 mm; width of head 5 mm, of abdomen 6.5 mm.

The head is considerably narrowed behind the eyes, and the hind angles are rough hairy; lateral setae six; mental setae eight or nine, the six or seven external ones forming a stronger series; the movable hook is stout, short and almost straight; dorsal hooks on abdominal segments 4–8, straight and sharp; lateral spines spinulose hairy externally, those of the ninth segment shorter than the 10th segment, 9th segment a little more than twice as long as the 10th; appendages as long as the last two segments, the lateral appendages half as long as the others.

### Libellula quadrimaculata Linnaeus

1785 Libellula quadrimaculata Linnaeus, Syst. nat. 1: 543

1861 Libellula quadrimaculata Hagen, Synopsis Neur. N. Am. p. 150

1867 Libellula quadrimaculata Packard, Am. nat. 1: 310, pl. 9, fig. 2

1893 Libellula quadrimaculata Calvert, Am. ent. soc. Trans. 20: 258

1893–97 Libellula quadrimaculata Calvert, N. Y. ent. soc. Jour. 3: 47 and 5: 94 (listed from New York, Ithaca, Schoharie, Karner and Buffalo)

1899 Libellula quadrimaculata Kellicott, Odon. Ohio, p. 100 (description)

1900 Libellula quadrimaculata Williamson, Dragon flies Ind. p. 331 (description)

This species occurred sparingly at Saranac Inn. A few imagos were seen sitting on twigs which rose directly a few feet out of the water. They were shy and difficult to capture, and, when disturbed, would rarely return to the same vicinity. I have not been able to find this so common species in its immature stages in person, but I have nymphs sent me from Ellenville N. Y. by Chester Young, and others from the state of Washington; these agree well with specimens from France which I have received from my esteemed correspondent, M. René Martin, of Leblanc. The nymph of this species has long been known in Europe.

**Nymph.** The largest Ellenville nymph, apparently full grown, measures in total length 26 mm; abdomen 18 mm; hind femur 6 mm; width of head 6 mm, of abdomen 8 mm.

The head is very compact in this nymph, scarcely narrowed behind the eyes; the median lobe of the labium is produced at the middle of its free border into a flat, toothlike prominence; lateral setae seven; mental setae about 13, of which the seven outermost are longest; movable hook slender and incurvate; the dorsum of the body is scurfy hairy (hardly less so than in L. pulchella, described below), and the hairs partly obscure the dorsal hooks which are present on segments 3–8 of abdomen, that of the eighth segment short and rudimentary; lateral spines very short; segment 10 about half as long on the dorsal as on the ventral side; appendages fully as long as the last two abdominal segments. The laterals have unusual length for a member of this genus in being but about one fourth shorter than the others.

## Libellula semifasciata Burmeister

Plate 23, fig. 1

1839 Libellula semifasciata Burmeister, Handb. ent. 2:862
1861 Libellula semifasciata Hagen, Synopsis Neur. N. Am. p. 151
1839 Libellula ternaria Say, Acad. nat. sci. Phil. Jour. 8:21
1842 Libellula maculata Rambur, Ins. Neur. p. 55
1893 Libellula semifasciata Calvert, Am. ent. soc. Trans. 20:258
1895–97 Libellula semifasciata Calvert, N. Y. ent. soc. Jour. 3:47 and 5:94 (listed from New York, Dobbs Ferry and Buffalo)
1898 Libellula semifasciata Needham, Outdoor studies, p. 55, fig. 54
1899 Libellula semifasciata Kellicott, Odon. Ohio, p. 100 (description)
1900 Libellula semifasciata Williamson, Dragon flies Ind. p. 332 (description)

In the north this species is the earliest of the genus to be abroad in the spring, making its appearance before the middle of May. I have oftenest found the imago about woodland brooks—rarely about ponds. I have never found the nymph; it is still unknown.

## Libellula pulchella Drury

Plate 23, fig. 2

1773 Libellula pulchella Drury, Illus. exotic ent. v. 1, pl. 48, fig. 5
1857 Libellula confusa Uhler, Acad. nat. sci. Phil. Proc. p. 87
1861 Libellula pulchella Hagen, Synopsis Neur. N. Am. p. 153
1893 Libellula pulchella Calvert, Am. ent. soc. Trans. 20:259
1895–97 Libellula pulchella Calvert, N. Y. ent. soc. Jour. 3:47 and 5:94 (listed from Keeseville, Dobbs Ferry, New York, Ithaca, Schoharie and Buffalo)
1898 Libellula pulchella Needham, Outdoor studies, p. 56, fig. 55
1899 Libellula pulchella Kellicott, Odon. Ohio, p. 101 (description)
1900 Libellula pulchella Williamson, Dragon flies Ind. p. 332 (description)

This beautiful, pond-loving species is one of the best known of all Odonata peculiar to North America. The old and white pruinose males hovering over the open water under the summer sun are certainly sufficiently striking to catch the eye of the most casual observer. The species was not common at Saranac Inn. But a few specimens were seen there. I reared one specimen there, many at Ithaca (where the species is abundant) and many in Illinois.

**Nymph.** Total length 26 mm; abdomen 16 mm; hind femur 6 mm; width of head 6 mm, of abdomen 8 mm.

All the ridges on the dorsum of this nymph are fringed with stiff, strong, erect hairs; these are specially marked about the borders of the prothoracic shield, and on the rear of the head; the labium is rather regularly rounded on the prominent median lobe, lacking the median toothlike prominence of some of the other species; the lateral setae are eight to nine; mental setae 12–13, the seven outermost each side longest; the lateral spines are moderate; the dorsal hooks are quite distinctive, being represented only on segments 4–6, rudimentary, or sometimes wanting altogether. Among my Ithaca nymphs were a good many on which I could find no dorsal hooks at all. My Illinois specimens agree with the nymph from Peoria Ill., figured by Cabot,[1] and referred by doubtful supposition to Neurocordulia obsoleta.

### PLATHEMIS

There is a single species within our limits.

## Plathemis lydia Drury

Plate 24, fig. 1

1770 Libellula lydia Drury, Illus. exotic ent. 1:112, pl. 47, fig. 4
1773 Libellula trimaculata DeGeer, Mem. ins. 3:556, pl. 26, fig. 2
1854 —— —— Emmons, Agric. N. Y. v. 5, pl. 15, fig. 4 and 5 (no name or description)

[1] Immature state of the Odonata. pt 3, pl. 6, fig. 6.

1867 Libellula trimaculata Packard, Am. nat. 1:310, pl. 9, fig. 1
1861 Plathemis trimaculata Hagen, Synopsis Neur. N. Am. p. 149
1873 Libellula trimaculata Riley, Ins. Mo. 5th rep't, p. 14 (This article contains a woodcut of this species which has been most extensively copied in this country.)
1893 Plathemis trimaculata Calvert, Am. ent. soc. Trans. 20:259
1895–97 Plathemis trimaculata Calvert, N. Y. ent. soc. Jour. 3;47 and 5:94 (listed from New York, Dobbs Ferry, Ithaca, Schoharie, Albany and Buffalo)
1898 Libellula trimaculata Needham, Outdoor studies, p. 57 and 65, fig. 56 and 66
1899 Plathemis trimaculata Kellicott, Odon. Ohio, p. 102 (description)
1900 Plathemis lydia Williamson, Dragon flies Ind. p. 333 (description)

This is another well known, widely distributed and generally common species, which inhabits ponds and ditches generally. I present herewith (fig. 32) a figure of its nymph, which I have previously published in *Outdoor studies.* It differs from Libellula and Ladona in having the head widest behind the eyes, and from Libellula in having the front margin of the median lobe of the labium crenulate.


Fig. 32 Dorsal view of nymph of Plathemis lydia Dru.

**Nymph.** Total length 24 mm; abdomen 14 mm; hind femur 4.5 mm; width of head 4.5 mm, of abdomen 5.5 mm.

Body elongate, rather smooth, and more free from dirt than most Libellulas, generally showing two bands of blackish brown extending from beneath the tips of the wing cases to the bases of the lateral appendages. Head not widened behind the eyes, but with sides parallel; median lobe of labium prominent, but with no middle tooth on its fore margin; lateral setae 10; mental setae eight; of which the five outer ones are longer; abdomen triquetral, with moderate lateral spines on segments 8 and 9, and with rudimentary dorsal hooks on segments 3–5, highest on the fourth segment, absent from the hinder segments; lateral appendages about half as long as the equal superior and inferiors.

### TRAMEA

But two species of this large genus seem to belong to the New York fauna. These are insects of superb aerial powers, representing, together with the next genus, the extreme of specialization in wing development, at least for the subfamily. Our two species may be recognized, even while in flight, by the broad, basal colored band on the hind wings. The nymphs agree in having the body smooth, depressed, unusually clean and marked with a pattern of brownish on a ground of clear transparent green;

head widest across the eyes, which are set well back toward the hind angles, the widest point being a little posterior to the middle of the head; rear of head abruptly rounded and a little concave on the hind margin; legs long, thin; tarsi with the second and third joints each twice the length of the first; abdomen strongly depressed, without dorsal hooks; dorsum smooth, with a pattern of paler mottlings on a darker ground; lateral spines of the eighth segment one and one half times as long as the body of the ninth segment, those of the ninth segment longer, reaching the level of the tips of the superior appendage; 10th segment about half as long as the ninth; appendages longer than the last two abdominal segments, superior a very little shorter than the inferiors, laterals one fourth as long; external margins of superior and inferior appendages and of the lateral spines spinulose.

These unusually attractive nymphs live in the midst of green vegetation about the shores of ponds and lakes.

Our two species may be distinguished as follows.

*Imagos*

*a* Mature coloration of the basal patch of the hind wings reddish.. carolina
*aa* Mature coloration of the basal patch of the hind wing blackish.. lacerata

*Nymphs*

*a* Fourth joint of the antenna three fourths as long as the third ... carolina
*aa* Fourth joint of the antenna one half as long as the third ....... lacerata

### **Tramea carolina** Linnaeus

1763 Libellula carolina Linnaeus, Centur. ins. p. 28
1861 Tramea carolina Hagen, Synopsis Neur. N. Am. p. 143
1890 Tramea carolina Cabot, Immature state Odon. pt 3, p. 46, pl. 6, fig. 2
1893 Tramea carolina Calvert, Am. ent. soc. Trans. 20:255
1895-97 Tramea carolina Calvert, N. Y. ent. soc. Jour. 3:47 and 5:94 (listed from New York city and Schoharie)

A large and very handsome species that is common all along our southern coast, and is distributed sparingly throughout the Mississippi valley.

**Nymph.** Total length 25 mm; abdomen 15 mm; hind femur 7.5 mm; width of head 7.5 mm, of abdomen 9 mm.

Save for the slightly larger size and a slightly darker general color, I can find no differences between this nymph and that of T. lacerata excepting the ones stated in the table: I find but 10 lateral setae in my nymphs of carolina, while generally there is an added shorter one at the proximal end of the row in lacerata.

## **Tramea lacerata** Hagen

1861 *Tramea lacerata* Hagen, Synopsis Neur. N. Am. p. 145
1890 *Tramea lacerata* Cabot, Immature state Odon. pt 3, p. 46, pl. 6, fig. 1
1893 *Tramea lacerata* Calvert, Am. ent. soc. Trans. 20 : 255
1895–97 *Tramea lacerata* Calvert, N. Y. ent. soc. Jour. 3 : 47 and 5 : 94 (listed from Freeville and Buffalo)
1899 *Tramea lacerata* Kellicott, Odon. Ohio, p. 94 (description)
1900 *Tramea lacerata* Williamson, Dragon flies Ind. p. 316 (description)

This species is likely to be found more generally distributed through the central part and in the higher altitudes of New York state than the preceding one. It flies throughout the greater part of the season. Pairs are often seen coursing the borders of ponds and ovipositing in early spring, and in August males are often seen out on the uplands, miles from water, foraging. They are exceedingly difficult to capture; but the nymphs are often found quite abundantly and are easily reared.

**Nymph.** Measures in total length 24 mm; abdomen 14 mm; hind femur 7.5 mm; width of head 7.5 mm, of abdomen 9 mm.

Characters as stated for the genus: there is a middorsal paler line on the abdomen, distinguishable among the other paler markings; there is a little proximal seta on the lateral labial lobe added to the 10 that are always present in *carolina*; the hook is very long and slender and incurvate at end as in that species; the mental setae are 14–15, as in that species, with the outer 8 or 9 very close set and longer.

### PANTALA

Our state can claim but a single species.

## **Pantala flavescens** Fabricius

1798 *Libellula flavescens* Fabricius, Ent. syst. suppl. p. 285
1861 *Pantala flavescens* Hagen, Synopsis Neur. N. Am. p. 142
1890 *Pantala flavescens* Cabot, Immature state Odon. pt 3, p. 43, pl. 6, fig. 5
1893 *Pantala flavescens* Calvert, Am. ent. soc. Trans. 20 : 254
1895 *Pantala flavescens* Calvert, N. Y. ent. soc. Jour. 3:47
1899 *Pantala flavescens* Kellicott, Odon. Ohio, p. 93 (description)
1900 *Pantala flavescens* Williamson, Dragon flies Ind. p. 315 (description; recorded from New York state)

This cosmopolitan species is apparently rare within our limits.

**Nymph.** Measures in total length 25 mm; abdomen 15 mm; hind femur 7 mm; width of head 7 mm, of abdomen 8 mm.

Body clean, smooth, depressed, very similar to *Tramea*, with rows of four to six black dots arranged transversely near the apex of abdominal segments 5–8, paired blotches at the middle of the sides of segment 7, at the lateral margins of segment 8, and near the middorsal line of

segment 9; black markings suffusing segment 10; a black mark on the middle of each of the inferior appendages; lateral setae 12 to 14; mentals about 15, the nine outer ones longer; teeth obliquely oval, as high as wide, spinulose at apex; tarsus with its second joint twice as long and its third, thrice as long as the first.

No dorsal hooks at all; lateral spines long, a little incurvate; those of the eighth segment reaching the level of the apical border of the ninth segment; those of the ninth segment twice as long as that segment, their apices reaching the level of the tips of the lateral appendages; superior appendage as long as or a little longer than the inferiors; laterals one fifth shorter.

The nymphs of this genus may be distinguished from those of Tramea by the greater length of the superior abdominal appendage, by the greater depth of the incisions between the teeth on the opposed margins of the lateral labial lobes, and by the brevity of the movable hook—hardly longer than the teeth, while in Tramea it is nearly as long as the setae.

## Order NEUROPTERA

### *Ant lions, aphis lions, dobsons, etc.*

Of this group as now delimited by most entomologists, a small proportion is aquatic, constituting one family (Sialidae) and part of another (Hemerobiidae). Members of the order agree in the possession of carnivorous habits and in their type of metamorphosis, and in little else. The families of Neuroptera occurring within the state of New York may be separated by the following table.

#### KEY TO THE FAMILIES OF NEUROPTERA

*a* Antennae enlarged toward the tip, club-shaped, or with a terminal knob (Larvae terrestrial: ant lions, etc.; the commoner ones make the well-known "pitfalls" in sand or dust in sequestered places. Pupa inclosed in cocoon of silk, hidden in the same places as those in which the larva lives) Myrmeleonidae

*aa* Antennae without terminal enlargement

*b* Fore legs fitted for seizing prey, stouter than the other legs; attached to the front end of an extremely long prothorax

(The larvae, so far as known, live parasitically in the nests of spiders and wasps, and transform to pupae in the same places within a cocoon of silk) .......... Mantispidae

*bb* Fore legs not thicker than other legs; not fitted for grasping; not attached at the front end of a very long prothorax

*c* Wings with few and simple veins, and covered with a whitish powder (Minute and rare insects; larvae, so far as known, arboreal; feeding on aphids; pupating in a double layered cocoon of silk) Coniopterygidae

*cc* Wings with many veins and not covered with whitish powder

*d* Wing veins all terminating at the distal border of the wing in a succession of symmetric forks, the ultimate forks often forming a peripheral zone around the distal margin of the wing

*e* Cross veins between the radius and its sector numerous (ten or more) (Green or yellowish insects: lace wing flies; larvae, aphis lions, arboreal; pupating in cocoon of silk, attached to the plants on which they have lived)............................Chrysopidae

*ee* Cross veins between the radius and its sector few (two to six) Hemerobiidae

*dd* Wing veins meeting the outer wing margin in straight lines. Forks fewer, more remote from the margin and less symmetric.. Sialidae

The two families which contain our aquatic species will now be considered in detail. Their larvae have already been distinguished in the key to the orders of aquatic insect larvae.

## Family SIALIDAE

### *Alder flies, fish flies, dobsons, etc.*

This family comprises but few genera and species; but the large size and the enormous number of individuals of some of the species make them a well known part of the aquatic population. Few insects of inconspicuous coloration and secretive habits are so well known. Every species, in larval as well as adult stages, is attractive food for fishes, and many of them are among the insects most highly prized and most commonly used for bait.

The adult insects do not wander far from the borders of their native streams or ponds; they are generally found sitting closely on some support, with wings folded like a roof over the back. They fly but little.

The larvae are somewhat cylindric, with large heads and very large raptorial mandibles, and have on the sides of each of the first seven or eight abdominal segments a pair of long, conspicuous lateral filaments.

The eggs are deposited on any convenient support near the water, in clusters whose form varies with the genus, and to a less extent, with the species.

Our three genera may be distinguished as follows.

#### KEY TO GENERA OF SIALIDAE

*Imagos*

*a* Fourth segment of the tarsus bilobed; posterior branch of the radial sector forked. No ocelli.............................................Sialis

*aa* Fourth segment of the tarsus simple, cylindric; posterior branch of the radial sector simple. Three ocelli

Hind angles of the head rounded; the median vein two branched; antennae with segments enlarged distally................Chauliodes

*bb* Hind angles of the head bearing a sharp angulation or tooth; median vein three-branched; segments of the antennae cylindric Corydalis

*Larvae*

*a* The last abdominal segment produced in a long, median, laterally fringed tail like process; a pair of lateral filaments on abdominal segments 1–7 Sialis

*aa* Last abdominal segment bifurcated, the fleshy forks each bearing a pair of hooks and a minute, external, lateral filament; conspicuous lateral filaments on abdominal segments 1–8

*b* Lateral filaments with no tuft of fine tracheal gills at their bases Chauliodes

*bb* Lateral filaments each with a tuft of fine tracheal gills at its base Corydalis

### SIALIS

*Alder fly*[1]*: orl fly*

A single species of this genus is recorded from this state.

### Sialis infumata Newman

*Smoky orl fly*

Plate 29, fig. 3

1838 Sialis infumata Newman, Ent. mag. 5:500

1853 Sialis infumata Walker, Cat. neur. ins. Brit. mus. 3:195

1861 Sialis infumata Hagen, Synopsis Neur. N. Am. p. 188

1863 Sialis infumata Hagen, Ent. soc. Phil. Proc. 2:180

1863 Sialis infumata Walsh, Ent. soc. Phil. Proc. 2:261–62 (figure of male genitalia)

1892 Sialis infumata Banks, Am. ent. soc. Trans. (listed)

1888 Sialis infumata Howard, Insect life, 1:99 (Sialis larvae in pools with Simulium)

This is a dusky brownish fly, often seen with wings closely folded sitting on sedge leaves near quiet waters. It may be taken with the fingers; but, if the fingers close too slowly, it will fall to the ground, kick vigorously several times to push itself into some crevice or tangle of stems and lie very quietly; then it will be difficult to find again. The collector may take advantage of this habit by bringing his opened cyanid bottle up to the insect from below.

This species is widely and generally distributed over the United States, and is often very abundant, specially westward. I have seen the grassy

[1] So called in England because often found on alders overhanging tranquil streams.

shores of a pond at Galesburg Ill. black with these flies about the beginning of June.

Several adults were taken on both Little Clear and Big Clear creeks, during the latter half of June. Larvae were obtained in small numbers from Little Clear creek on the hatchery grounds. No attempt was made to rear them. I have reared the species in Ithaca N. Y. in 1897. Larvae obtained here agree entirely with others from Ithaca and from Galesburg Ill.

The larvae live in trashy places filled with aquatic plants in the borders of streams and ponds. They clamber through fallen vegetation with great agility, and push their way readily through sediment fallen on the bottom. In an aquarium, and probably outside, the abdomen maintains an undulating motion, the long tail being intermittently lashed up and down. This causes a swirl in the water, which is doubtless useful in bringing a fresh supply of water into contact with the lateral filaments.

The larvae, when fully grown, transform in moist soil at some little distance from the edge of the water. At a depth of several inches or a foot or more, depending on the character of the soil, an oval cell is formed in which the larva curls itself up, and without making a cocoon becomes a pupa. Two or three weeks after the making of the pupal cell the adult fly emerges.

Excellent available accounts of European species of Sialis are:

**Pictet, F. J.** Mémoire sur le genre Sialis Latreille, etc. Ann. sci. nat. (2) 1836. 5:69–80, 1 colored pl. (life history)

**Nunney, W. H.** Development of the alder fly. Science gossip. n. s. 1895 2:257–58.

**Miall, L. C.** The alder fly. Natural history of aquatic insects, p. 273–8, 1895.

**Larva** (Pl. 29, fig. 3) Measures in length 22 mm, including a tail 4 mm long; width 2.3 mm. Head and thorax of equal width, abdomen very slowly tapering.

Color yellowish, darker on the abdomen; a middorsal line of brown extending from the middle of the head to the base of the abdomen, interrupted on the middle of the prothorax; an arrow-shaped mark on the frons, and a brown line extending obliquely inward from the hind angles of the head. Sides of thorax mottled with yellow and brown. Abdomen brownish or purplish with paler sutures and a pair of submedian, dorsal ( )-marks on the middle abdominal segments.

Head depressed, subquadrangular, with rounded angles, and projecting mouth parts; prothorax subquadrangular, as large as the head, and about as large as the two succeeding segments of the thorax taken together.

Abdominal segments 4–7 of about equal length, 3, 2 and 1, successively, each a little shorter; segment 9 a little shorter than 8; 10 drawn out into the tapering, lashlike filament 4 mm long; the filament marked with black at two thirds its length and laterally fringed with yellowish

hairs; lateral filaments more or less distinctly 5-segmented, tapering, sparsely fringed with hairs, increasing in length posteriorly, on segment 1 as long as the width of that segment; on segment 7 twice as long as on 1.

Body smooth; legs smooth at bases, hairy toward the tip, yellow; tarsal claws unequal, tipped with black. As with other semi-burrowers and burrowers, the forelegs are closer together at base that are the legs of the other pairs.

**Pupa.** (Pl. 29, fig. 2.) Length (coiled) 9 mm; width of head 3.7 mm, of abdomen 4 mm.

Body clad with soft, fine hairs, specially on head and thorax; head and appendages pale yellow, varying with age. Thoracic dorsum yellowish with broad, brownish or purplish marks at sides and on front margins of segments; abdomen short, thick, accurate, with obtuse but prominent lateral margins, narrowed a little at both ends; no sharp angles or spines on any of the segments; apical segments mainly yellow; the others suffused more or less with brown or purple tending to be arranged in a pattern as follows: a middorsal, narrow line; a dorsolateral interrupted band; a lateral row of dots, three ventral rows each side of unequal marks, confluent in stripes or interrupted; sutures all darker. There is a transverse, anteapical, impressed line of brown on the middle abdominal segments.

## CHAULIODES

Of the eight nominal North American species of this genus, but two are recorded from this state. These two and a third occur at Saranac Inn.

These insects are less secretive than those in other genera of the family. Imagos of some species of Chauliodes at least are abroad habitually during hours of sunshine, making short, fluttering flights from stem to stem. They rest most of the time: resting or flying, they are easily taken with a net.

The eggs are placed in somewhat regular rows on the surface of some leaf or other support; sometimes over water, but oftener at a short distance from it.

The larvae live in wet places at the edge of the water, or in water close to the surface, and are perhaps oftenest found clinging to the under side of floating logs or crawling beneath the loosened bark. They crawl rapidly and cling securely by means of the claws on the thoracic legs and on the bifurcated tenth abdominal segment. They swim but poorly by means of undulations of the abdomen and lashing of the lateral filaments.

The lateral filaments are less important respiratory organs than in Sialis. While they contain tracheae, they also contain a larger proportion of muscle and are covered by thicker integument. There are nine pairs of well developed spiracles, one pair in the sides of the prothorax at its hind margin, and one on each of the first eight abdominal

segments, situated just above the bases of the lateral filaments. The pair on the eighth segment is more or less elevated above the surface of the segment, being more or less extended in flexuous respiratory tubes. These tubes may reach a length exceeding that of the lateral filaments. They enable the larva to remain below while taking air at the surface of the water.

The genus is semiaquatic.

The full grown larva finds a place above the level of the water under a stone or log or layer of moss or in a rotten log and excavates a cell in moist soil or in rotten wood, in which without spinning a cocoon it enters on a pupal period of about two weeks' duration.

Three species of Chauliodes larvae were taken in the edges of Little Clear pond and creek. None of them were raised. One of them agrees with the larva figured as Ch. pectinicornis [1] by J. Bridgham in Dr Lintner's eighth report as entomologist of the state of New York (1893. pl. 1). Another is distinguished by its size: it is too large to be the larva of any known New York species save Ch. pectinicornis. The third one should belong to Ch. rastricornis,[2] and probably it does; for it agrees with the larva of that species as figured by Prof. Weed, and copied in the above mentioned report of Dr Lintner. Since no specific differences in habits were noted for these larvae save that the one referred to Ch. pectinicornis was less aquatic, and since they can not be referred to the species discussed below with positive certainty, the structural differences between them may as well be briefly indicated here.

*a* The spiracles of the eighth abdominal segment widely separated, their margins elevated but slightly above the level of the segment
Ch. pectinicornis, supposition

*aa* Spiracles of the eighth abdominal segment approximated and drawn out into a pair of long, flexuous, contractile respiratory tubes which surpass the tip of the abdomen

*b* Respiratory tubes conspicuously unequal in length; the 10th abdominal segment including its claws two and a half times the length of the ninth; the lateral filament of the 10th segment surpassing the tips of the claws by more than the length of the claws
Ch. serricornis, supposition

*bb* Respiratory tubes about equal in length; the 10th abdominal segment with its claws one and a half times the length of the ninth; the lateral filament of the 10th segment surpassing the tips of the claws by less than the length of the claws...... Ch. rastricornis, supposition

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1 This, I take it, was a case of mistaken determination. The larva was not reared; it is too small to belong to pectinicornis; it is like larvae of Ch. serricornis, bred by Mr Henshaw and in the Museum of comparative zoology. I therefore refer it to that species.

2 Ohio agric. exp. sta. Tech. ser. Bul. 1889. 1:7-10, pl. 1, fig. 3.

## Chauliodes rastricornis Rambur

1842 Ch. rastricornis Rambur, Ins. Neur. p. 444

1853 Ch. rastricornis Walker, Cat. neur. ins. Brit. mus. 3: 198

1861 Ch. rastricornis Hagen, Synopsis Neur. N. Am. p. 189

1863 Ch. rastricornis Hagen, Ent. soc. Phil. Proc. 2: 181

1863 Ch. rastricornis—Walsh, Ent. soc. Phil. Proc. 2: 263–64 (larva described and distinguished from Corydalis larva)

1889 Ch. rastricornis Weed, Ohio agric. exp. sta. Tech. ser. Bul. 1: 7–10, pl. 1, fig. 3 (life history)

1892 Ch. rastricornis Banks, Am. ent. soc. Trans. 19: 357 (listed)

Ch. rastricornis Lintner, N. Y. state ent. 8th rep't. p. 158–59 (notes on distribution)

To the excellent account of this insect given by Professor Weed we have nothing to add save a few notes as to its occurrence at Saranac Inn. The imago was not observed at all outside our breeding cages. Larvae and pupae were obtained in several places about the shores of Little Clear pond.

June 14 Dr Felt and I, while looking over the ground preparatory to beginning regular operations, rowed into the little bay on the west side of Blueberry island in Little Clear pond and found the species in abundance. The bank was overhung with clumps of fragrant Labrador tea, and here and there lay a rotting hemlock log half in the water and half out, the exposed portion bearing an ornamental covering of matted moss and sundew plants. Our boat touched shore beside one of these logs; and there was a hole in the rotten wood, with an empty pupa skin hanging out of it. We followed this clue, and, examining the log, found the Chauliodes pupae. By pulling apart the crumbling fragments with our fingers, we in a very little while found in this and a few other logs near by, 25 pupae. One of these transformed on the way home, and the imago was lost; three were raised; a number were preserved for specimens, and the remainder died. On the 16th I returned to this place again, and found that by this time many had transformed. There were still plenty of pupae to be found, however, by diligent searching of the partly submerged and crumbling logs.

Chauliodes eggs, which I took to belong to this species, were not uncommonly found attached to the flat surface of some old, gray snag or board several feet above the surface of the water. They were more grayish in color than the eggs of Ch. serricornis, and were arranged in somewhat more regular V-shaped rows, and never more than one layer in depth. I saw a number of clusters about July 1 on the side of the boathouse facing the pond. These, as well as the clusters

found on snags about the lake shores, were very generally parasitized, by the very minute egg parasite, Trichogramma minutum Riley. The proportion of the eggs thus destroyed in a number of clusters collected in several places, was found by count to exceed 70%. As will be noted below, a great number of clusters of eggs of Ch. serricornis were hatched under observation. Among these not a single egg parasite was observed.

## **Chauliodes pectinicornis** Linnaeus

*Comb-horned fish fly*

Plate 26, fig. 1

1763 Hemerobius pectinicornis Linnaeus, Amoen. acad. 6:412

1767 Hemerobius pectinicornis Linnaeus Syst. nat. Ed. 12, v. 1, pt 2, p. 911

1775 Hemerobius pectinicornis Fabricius, Syst. ent. p. 309,

1781 Semblis pectinicornis Fabricius, Spec. ins. 1:386

1787 Semblis pectinicornis Fabricius, Mant. ins. 1:244

1807 Chauliodes pectinicornis Latreille, Gen. crust. ins. 3:198

1862 Chauliodes pectinicornis Hagen, Synopsis Neur. N. Am. p. 189 (description of imago)

1863 Chauliodes pectinicornis Hagen, Ent. soc. Phil. Proc. 2:181 (mention)

1869 Chauliodes pectinicornis Walsh-Riley, Am. ent. 1:245 (characters of imago)

1869 Chauliodes pectinicornis Packard, Guide study ins. p. 607

1873 Chauliodes pectinicornis Hagen, Bost. soc. nat. hist. Proc. 15:29 (mention)

1874 Chauliodes pectinicornis Pettit, Can. ent. 6:45 (occurrence in Canada)

1877 Chauliodes pectinicornis Moody, Psyche. 2:52 (description (in part) and habits of larva)

1878 Chauliodes pectinicornis Riley, Can. ent. 11:97-98

1879 Chauliodes pectinicornis Riley, Am. ass'n adv. sci. Proc. p. 286-87 (eggs and characters of larvae)

1888 Chauliodes pectinicornis Comstock, Introd. ent. p. 220

1888 Chauliodes pectinicornis Packard, Ent. for beginners, p. 87 (mention)

1895 Chauliodes pectinicornis Comstock, Manual stud. ins. p. 178

Chauliodes pectinicornis Lintner, N. Y. state ent. 8th an. rep't. p. 155-59 (a full account with digest of preceding papers and original figure of imago (text fig. 15) and remarks as to its probable economic status)

A single female[1] specimen was bred from a pupa found in an old pine

[1] This female was caged in a trap lantern (from which the cyanid was omitted) for a night and part of two days, in the hope of luring males, but without result.

stump in the edge of the water near the outlet of Little Clear pond. The pupal cell was located in red-rotten wood, fracturing, but not crumbling, and was about a foot above the level of the water. Soon after transformation the photograph reproduced in pl. 26, fig. 1 was taken. It shows beside the imago, a piece of the stump, the broken cell, and the pupal skin.

This is the largest of the ashen gray species of Chauliodes. It measures in length to tip of wings 54 mm. Expanse of wings 95 mm. It has sometimes been confused with the other common gray species Ch. rastricornis, but may readily be distinguished by the characters tabulated below.

| CHARACTERS COMPARED | RASTRICORNIS | PECTINICORNIS |
|---|---|---|
| antennae of female | serrate | pectinate |
| embossed markings on head and prothorax | black on a paler ground | yellow on a black ground |
| prothorax | longer than wide | not longer than wide |
| radial sector | 5–6 branched | 7 branched |
| pale fuscous spots on fore wings | indistinct, isolated | meeting in narrow, transverse bands across the middle of the wing |
| base of the upper limb of first fork of radical sector, as far as the first cross vein in cell $R_1$ | black | mostly white |

Near the place where the insect was found in a stump the larvae referred to this species by supposition were taken: one on July 18, apparently fully grown, and two smaller ones June 30.

The full grown larva measured 55 mm in length; width of prothorax 5 mm; length of respiratory tubes on eighth abdominal segment only .7 mm. (Ch. serricornis larvae, length 36; of respiratory tubes 5; width of prothorax 3).

Color yellowish brown, darker on head and prothorax; margins of sclerites yellowish; clypeus yellow; labrum reddish brown. Legs yellowish, washed with brown exteriorly. A longitudinal mark of brown at

the base of each of the lateral filaments of the tenth abdominal segment on its inner side. Other characters as given in the table for larvae above.

## **Chauliodes serricornis** Say

*Saw-horned fish fly*

Plate 27

1821 Chauliodes serricornis Say, Acad. nat. sci. Phil. Jour. v. 2, appendix p. 307

1839 Chauliodes serricornis Burmeister, Handb. ent. 2 : 949

1842 Neuromus maculatus Rambur, Ins. Neur. p. 442, pl. 10, fig. 2

1853 Neuromus maculatus Walker, Cat. Neur. ins. Brit. mus. 3 : 202

1861 Chauliodes maculatus Hagen, Synopsis Neur. N. Am. p. 190

1863 Chauliodes serricornis Walsh, (Corrects Hagen's names) Ent. soc. Phil. Proc. 2 : 262

1892 Chauliodes serricornis Banks, Am. ent. soc. 19 : 357 (listed)

1893 Chauliodes serricornis Lintner, N. Y. state ent. 8th an. rep't, p. 157 (notes on its occurrence in New York state, with original figure ; larva described and figured as Ch. pectinicornis ? )

This species was very common on Little Clear creek between the hatchery and the railroad. Half a dozen specimens could be picked from the sedges and flowering ferns in walking across this short open space any day in July. When resting on the under side of the leaves of the flowering fern, Osmunda regalis Linn., they were not easily disturbed; several were carried into the hatchery on a fern spray. A pair found *in copulo* was thus carried in and photographed (pl. 27); these pictures show the singular position assumed by the male in copulation. In this case, though not in any other of the many observed, the female had apparently already deposited a large number of eggs. Shortly after photographs *a* and *b* of the plate were taken the male departed, and the female resumed ovipositing. She added eggs at first in regular series, following the lines of the cluster already laid down; finally depositing a partial second layer in less regular order on the top of the first. While thus at work, the photograph reproduced as fig. *c* of the plate was taken.

A large number of egg clusters were seen, all of them on the under side of leaves of the above mentioned fern. In the cluster shown in these figures there were about 900 eggs. Some larger clusters were seen; many of them were smaller. These eggs hatched in 17 days. There appears to be great uniformity in incubation period with eggs of the same cluster. Numerous clusters were picked with the eggs all hatching at once, heads protruding, and jaws widely swung open, a most curious sight, a veritable *cheval de frise* of great rapacious mandibles.

The newly hatched larva of Ch. serricornis is 3 mm long, and has much the same aspect as older larvae of the genus have. The head

and mouth parts are relatively larger. The lateral filaments bear two spinules at their apex, the posterior one minute. Each filament shows a central tracheal branch, without distinguishable tracheoles and with a rough prickly surface which is certainly not suggestive of a respiratory organ. The circulation of the blood, easily seen in other parts of the body, I could not observe in these at all.

Respiratory tubes from the spiracles of the eighth abdominal segment, wide apart, short, not half as long as the segment. The lateral filaments of the tenth abdominal segment are short, bearing three setae, of which the two exterior are longer than the filament itself: filament not surpassing the tips of the claws. The two longitudinal tracheal trunks within the body terminate in the tubes springing from the spiracles of the eighth abdominal segment, but they are much stouter anteriorly where passing the other spiracles, and they bend distinctly outward to meet the spiracles of the prothorax.

Antennae three-jointed, the second joint bearing at its distal end exteriorly a pair of spinules close beside the base of the terminal joint.

The brevity of the respiratory tubules on the eighth abdominal segment is doubtless ancestral; and the spinules on the lateral filaments may mean that these filaments are but modified larval setigerous tubercles. The function of the filaments is largely locomotor; they are used as fins in swimming. But they are also "outriggers," if we may so speak, serving to maintain the proper position of the long abdomen while crawling about over submerged logs.

Ch. serricornis was first taken June 20, and was quite common for a month thereafter. The pupa was searched for, but not found.

## Corydalis

Our sole species, C. cornuta Linn. is too well known to need another description. It will be recognized by the characters stated in the keys, and by Dr Lintner's figures, reproduced herewith as Plate 28.

## Family HEMEROBIIDAE

This family has received little attention from entomologists in America. I do not now recall a single American species whose life history is known in full. A single species supposed to be aquatic has been twice reported from the United States—once from New York state. It is gratifying therefore to be able to add another genus, Climacia, to the list of aquatic genera, and to make a slight contribution to the knowledge of its habits and life history.

### KEY TO GENERA OF HEMEROBIIDAE[1]

*a* Branches of the radical sector arising (i. e. separating from vein $R_1$) by a common stalk (fig. 32)

*b* Humeral cross vein recurrent, and bearing several branches on its outer side .................................................. Polystoechotes

*bb* Humeral cross vein unbranched and not recurrent

*c* The median vein repeatedly forked; some of the branches of vein $Cu_1$ forked .................................................. Sisyra

*cc* The median vein but once forked; the branches on vein $Cu_1$ simple .................................................. Climacia

*aa* Branches of the radial sector arising separately from vein $R_1$

*d* Humeral cross vein recurrent and bearing several branches on its outer side .................................................. Hemerobius

*dd* Humeral cross vein unbranched and not recurrent............ Micromus

The typical genus, Hemerobius, includes the majority of the described species of the family. Its larvae are commonly arboreal, and feed on aphids, small moth larvae, etc. They commonly spin their loose cocoons of silk in crevices of the bark and there undergo their transformations.

Of the American genus Polystoechotes, which contains our largest species, the life history has not been recorded. Hagen, characterizing the genus in 1861 (*Synopsis Neuroptera of North America*), wrote " Larvae perhaps aquatic "; and this opinion has been handed down to the present time. I obtained some of the eggs in July by confining some of the females of Polystoechotes in a pasteboard box. The eggs were dropped at random on the bottom of the box, where they rolled loosely about. They were chalky white in color, oblong oval in outline, with surface minutely granular. Some were dropped on water in a glass, where they floated high and dry; and the next day were overgrown with molds. The others were left in the box, and the box closed that more eggs might be obtained: instead, the females ate the eggs already laid, and then began to devour one another. Thus I lost an excellent opportunity for studying the earlier part of the life history of this interesting insect. The character of the eggs, and the haunts of the females lead me to suppose rather that the larva is terrestrial or arboreal, as in Hemerobius.

Polystoechotes punctatus (pl. 26, fig. 2) Fabr. was not uncommon during the month of July. It was taken a few times in our trap lanterns; but, for some, to me unknown reason, was found in numbers only in the Saranac Inn railway station. At the windows of the depot one might expect to gather with little effort a dozen or more specimens in an evening.

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[1] Three North American genera remain as yet unreported from New York state: Dilar, with a single species, distinguished from the remainder of the family by the possession of ocelli; Psectra, with a single species, distinguished by its having normally but two wings; and Berotha, with three species, distinguished by having the apex of the wing very acute, and a notch or excision in the outer wing margin.

Clearly, Dr Lintner found this species in far greater abundance at Long lake, Hamilton co. N. Y. in August 1885[1]; for he wrote of it, "Hundreds could be seen resting on the parlor walls."

But two hemerobian genera have been accounted aquatic hitherto. These are Osmylus, a European genus, whose life history has been fully made known by Hagen and Brauer, and Sisyra, whose larvae, common in fresh-water sponges in Germany and in England, seem to have been determined by exclusion; at least I have been unable to find any account of the rearing of the larvae or any description of the pupae or the cocoons. I reared many of the larvae at Saranac Inn during the past season; and bred also the American genus Climacia, of whose habits nothing seems to have been known hitherto. It also is aquatic, and, like Sisyra, lives on fresh-water sponges.

Larvae and pupae of these two genera may be separated as follows.

*Larvae*

*a* Setae on the dorsum of the thorax pedunculate (i. e. the setigerous tubercles elevated considerably above the level of the integument).... Climacia

*aa* Thoracic setae sessile........................................ Sisyra

*Pupae*

*a* Tips of the fore tarsi extending posteriorly beyond the apices of the maxillary palpi; the fifth segment of the latter less than twice the width of the fourth. Outer covering of pupal case of open regular hexagonal mesh Climacia

*aa* Fore tarsi and palpi with apices about on a level; fifth segment of the maxillary more than twice the width of the fourth. Outer covering of pupal case closewoven ........................................ Sisyra

## Sisyra

1771 DeGeer, Mem. pour servir á l'histoire nat. ins. v. 2, pt 2. German translation 1779: index, "Die schwarze haarichte Hemerobius, eine neue gattung," v. 2, pt 2, p. 71, no. 3. "Die schwarze, haarichte Hemerobius, mit hellbraunen flügeln und braungelblichen füszen." (A good detailed description of the species afterward named Hemerobius fuscatus by Fabricius, and made the type of the new genus Sisyra by Burmeister. Pl. 22, fig. 8 nat. size, fig. 9 more enlarged imago, fig. 10 head still more enlarged, fig. 11 fore wing)

1835 Stephens, Section C of genus Hemerobius. Illus. Brit. ent. 6: 114

1839 Sisyra Burmeister, Handb. ent. v. 2, pt 2, p. 975 (original description of the genus)

1840 Sisyra Wesmael, Acad. Brux. Bul. 8:4 of reprint, which only I have seen. The article is "Notice sur les hemerobides de Belgique." 19 p. 4 pl.

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1 "Collections in the Adirondack region in 1885," in his fifth report on the Injurious and other insects of the state of New York. Albany 1889. p. 286.

1842 Sisyra Rambur, Ins. Neur. p. 414–15
1851 Sisyra Hagen, Stett. ent. zeit. 12: 185–86 (bibliography)
1857 Sisyra Brauer, Fauna Austriaca; Neur. p. 55 and p. 22 of introduction
1858 Sisyra Hagen, Ent. annual p. 25
1861 Sisyra Hagen, Synopsis Neur. N. Am. p. 197
1868 Sisyra Brauer, Verh. k. k. zool.-bot. ges. in Wien. p. 398
1868 Sisyra McLachlan, Ent. soc. Lond. Trans. p. 166–67 (the fullest characterization of the genus)

*Larva*

1839 Westwood, "an anomalous insect found in the Spongilla fluviatilis" Mag. nat. hist. (2) 3:200; An. sci. nat. (2) 11:380
1840 Westwood, Introd. modern classification of ins. 2:586 (notes on the larvae, with some bad guesses as to their place in the system)
1840 Hogg. "Observations on Spongilla fluviatilis," Linn. soc. Lond. Trans. 18:390–92; Isis for 1843, review, p. 466
1842 Westwood. "Descriptions of some insects which inhabit the tissues of Spongilla fluviatilis," Ent. soc. Lond. Trans. 3:105–8, fig. (Names the larvae Branchiostoma spongillae)
1842 Erichson. Wiegm. arch. f. naturg. p. 91
1842 Rambur in Ins. Neur. p. 415, says the larva of Sisyra is aquatic
1844 Grube. Beschreibung einer auffallenden, an süsswasserschwämmen lebenden larve, Wiegm. arch. f. naturg. 11:331–37, fig. (refers the larvae to Sisyra)
1847 Haliday. On the Branchiostoma spongillae, and on Coniopteryx, Ent. soc. Lond. Trans. 5: Proc. 31–32
1848 Westwood. The Spongilla insect, Gardener's chronicle, p. 557
1851 Hagen. "Uebersicht der neueren litteratur betreffend der Neuroptera, Linne." Stett. ent. zeit. 12:185–86 (under Hemerobius [Sisyra] fuscatus Fabr., says that the larva is not known, but that it is probably the Branchiostoma spongillae of Westwood, since the adults are very abundant all through the summer, and are found only near water)
1855 Brauer. "Beiträge zur kenntniss des inneren baues und der verwandlung der neuropteren," Schriften des zool.-bot. vereins in Wien, p. 1–26, 5 pl. p. 3, "Die fragliche Sisyra-larve"
1858 Hagen. "Synopsis of the British planipennes," Ent. an. p. 25 (under Sisyra, says: "Larva lives in the water (Branchiostoma spongillae Westwood: cocoon?")
1866 Hagen. "Hemerobidarum synopsis synonymica." Stett. ent. zeit. 27:369–462 (on p. 388, says that the Branchiostoma is the larva of Sisyra fuscata Fabr.)

Subsequent papers repeat this statement, but I have been unable to find any account of the life history of the genus, or any description of the pupa or cocoon.

Anyone who will take the trouble to look through the published records of the larva of this dusky little fly will discover that it has had

an interesting history, and has occupied a unique place in our entomologic literature. Unlike the larva of the beetle, Psephenus, or that of the syrphus fly, Microdon, or the larval case of the caddis fly Helicopsyche, or the nymph of the May fly, Prosopistoma, all of which were for a time mistaken for mollusks, the Sisyra larva, was clearly an insect, but not referable by its discoverers to any definite place in the insect series. James Hogg first found it while studying fresh-water sponges, and J. O. Westwood brought it to the notice of the public. A discussion was then raging in the learned societies of the old world as to whether sponges belong to the plant or to the animal kingdom, and the Sisyra larva was dragged, an innocent victim, into this controversy. Dujardin, maintaining that sponges are animals, told the French academy that he found in the sponge body numerous fine filaments that moved to and fro. James Hogg, on the other hand, believing that sponges are plants, maintained before the Linnaean society of London that the filaments seen by Dujardin were the setae on the back of these larvae, which had crawled, as is their wont, into the sponge through the open osteoles.

The larva possessed two structures, also, so unique in character that interest in them has survived the sponge controversy, and on account of which the original figures of Westwood and Grube are handed down in textbooks of the present day. These peculiar parts are 1) paired, jointed appendages beneath the abdominal segments, and 2) long, decurved, piercing mouth parts, of a unique suctorial type.

Notwithstanding the interest attaching to this larva, it seems not to have been reared. That it belonged to Sisyra was, I take it, a logical deduction. The brief quotations which I have inserted in the above bibliography will serve to show how the conviction grew. The small size of the larva, and its certain Hemerobian affinities (the larva of other genera being known) left no doubt that it was Sisyra. I was unwilling to believe that it had not been reared till after consulting all the literature in which I could find any mention of it, and examining at Cambridge Dr Hagen's manuscript drawings illustrating hemerobian life histories and finding among them a larva well drawn, but no pupa or cocoon.

There are several European species of Sisyra: there is one North American species, S. vicaria Walker, described from Georgia, and afterward reported from New York.[1] The species I found at Saranac Inn is very close to the typical Sisyra fuscata Fabr. It differs

[1] Banks. Am. ent. soc. Trans. Possibly not vicaria.

from S. vicaria in being much larger, according to the measurements given in the extremely brief and uncritical published descriptions of that species. There is a specimen from Illinois in the Museum of comparative zoology, and I collected many specimens of both larvae and adults at Lake Forest Ill. in June 1899. I did not at that time rear the species, however. I describe it below as Sisyra umbrata n. sp.

In passing, I should call attention to an error almost uniformly committed in the characterizing of this genus: there is said to be no cross vein in the basal part of the subcostal space. As a matter of fact, that cross vein is almost always present, though it is sometimes not very distinct. I have examined specimens of three European species in the Museum of comparative zoology, among them a large series of specimens of the typical S. fuscata, as well as hundreds of specimens of the species described below, and have not noted the absence of this cross vein in a single case.

### **Sisyra umbrata** sp. nov.

Pl. 12, fig. 6, 7 and 33, 34, 36 text figures

Length to tip of wings, male 6 mm; female 8 mm; expanse of wings, male 12 mm, female 13 mm.

Color nearly uniform blackish brown. There is a faint wash of rufous on the face, the legs and the apex of the abdomen are dirty yellowish.

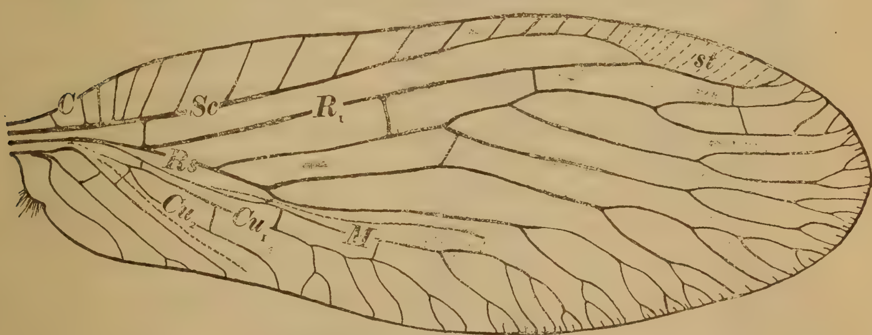


Fig. 33 Fore wing of Sisyra umbrata

Lake Forest Ill. June 1899; Saranac Inn N. Y. June 28 to July 16, 1900; abundant.

This is a stouter, larger, blacker, more hairy species than S. fuscata. The second segment of the antennae is nearly as large as the third and fourth together, and the third is little more than half the size of the fourth; in S. fuscata the second, third and fourth antennal segments are subequal, and the third is not distinctly smaller than the fourth. In

S. umbrata the last joint of both palpi is distinctly pediform (fig. 34, 36); I have not been able to examine the palpi with any degree of satisfaction in any specimen of S. fuscata, but according to Wesmael's figure[1] the terminal segment should be simply conic.

During the first week of our stay at Saranac Inn we scraped the surface water supply trough in the hatchery, and in the scrapings found about 100 small fresh-water sponges. A few of the larvae of this species were found on the sponges. Shortly the cocoons began to appear on the sides of the supply trough, and in such numbers that it was evident that the larvae were coming in from the pipes. The cocoons were located, some inside the supply troughs on the smooth, tarred, vertical sides just above the water, some on the upper edges, some on the sides and edges of the hatching troughs below, but mostly on the outside of the supply troughs and in the angles which they make with the hatching troughs, or in the thread grooves at the base of the faucets. Each larva spins over itself, a hemispheric cover of close woven silk (pl. 12, fig. 11), attached by its edges to the supporting surface, and a complete inner cocoon of considerably smaller size, likewise close woven.

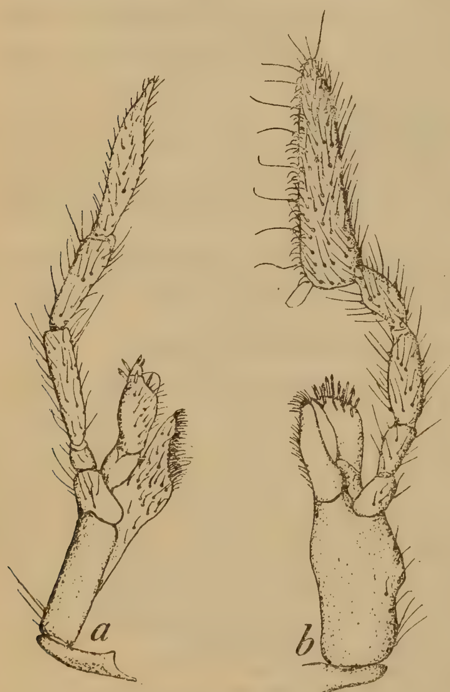


Fig. 34 Maxillae:
*a* of Climacia dictyona Ndm.
*b* of Sisyra umbrata Ndm.

Larvae of this species taken from unfinished cocoons and placed in a vial spun new cocoons in the corners of it under observation. It was interesting to watch them weaving back and forth their anal spinnerets, as the threads were laid down.

Two larvae of this species, taken just as they were leaving the water June 21 and placed in a vial plugged with cotton, spent at least 12 hours in spinning their cover and cocoon, and remained inactive larvae 24 hours longer. Then they transformed to pupae, which remained suffi-

[1] Acad. Brux. Bul. 1840. v. 7, fig. 3 of plate.

ciently active thereafter to kick vigorously whenever the vial was moved, The imagos emerged July 2, 11 days after leaving the water. The pupa makes its way through the side of the cocoon, and the empty pupal skin is left sticking in the hole when the imago flies away.

In the supply trough in the hatchery fresh-water sponges of small size were easy to find, and I saw the Sisyra larvae clinging to them, crawling over them, and apparently piercing them with their long, sharp decurved jaws. I also observed this later on a sponge-covered log in Little Clear pond. The larva clings closely to the sponge surface, lies in the hollows of it, or, sometimes, descends bodily into an open osteole. The numerous spines on its back usually carry a load of debris beneath which its form is well concealed. It can readily be driven about over the sponge surface, but will hardly be induced to take a step away from it on the bare wood.

The respiratory filaments are jointed and folded beneath the abdomen. They are moved intermittently in a rapid shuttle-like vibration.

Imagos on emergence seemed by preference to fly at once to the hatchery ceiling. They congregated on the best lighted portions of it. I stood in one spot on my work table and collected from the part of the ceiling within reach hundreds of specimens at a time. Nothing was easier. They would jump directly into an unstoppered bottle held close below them. Their flight to the ceiling on emergence suggests a probable reason why I was able to see so few specimens out of doors. There they probably fly directly to the tree tops—the home of their nonaquatic kin. A few specimens were taken at a trap lantern placed near the outlet of Little Clear pond. I caught one or two specimens close above the water while sweeping aquatic vegetation in Little Clear creek. These may have been females ovipositing, but I did not find their eggs. Neither did I get them, though I several times inclosed females in cages supplied with aquatic plants and with sponge-bearing pieces of wood.

A student in my laboratory at Lake Forest college is working on the anatomy and metamorphosis of this species. I prefer to leave the farther characterization of the several stages to the paper which will result from that work.

### CLIMACIA

1869 McLachlan. "New species of Hemerobina, with synonymic notes", Ent. month. mag. 1:27. The genus is carefully characterized, and is correctly allied with Sisyra, from which it is distinguished by the following characters, the first of which will not hold:

1 A single basal cross vein in the subcostal space
2 Two well defined series of gradate veins
3 Prothorax elongate
4 Face long and triangular
?5 Two curious setiform organs, apparently attached to the maxillae

That these last, whatever they may have been, were extraneous, is evident from an examination of the maxillae of fresh or alcoholic specimens (fig. 34). McLachlan had for examination only a few dried specimens. "Larva probably aquatic".

The single species of this genus hitherto known, C. areolaris Hagen has been reported only from the southern states. There are numerous specimens of it, however, in the Museum of comparative zoology from Waltham and Cambridge Mass., as well as a number from Florida. The species found at Saranac Inn and described below differs from areolaris in being of darker color on the wings (black, where areolaris is but brown), of larger size (females of areolaris do not exceed the measurements given by Hagen[1]), and in having the vein $Cu_1$ seven-branched (it is six-branched in areolaris).

## Climacia dictyona sp. nov.

Pl. 12, fig. 1, 2 and 34-36 text figures

**Imago.** Length to tip of wings, male 6 mm, female 8 mm; expanse of wings, male 11 mm, female 13 mm; length of antennae 5 mm.

Face yellow; eyes blackish; top of head rufous; thorax black; legs clear yellow beyond the coxae, excepting the extreme tips of the tarsi.

Wings smoky brown, varied with yellow and black. Pterostigma yellow, with a black mark each side; the proximal one curving

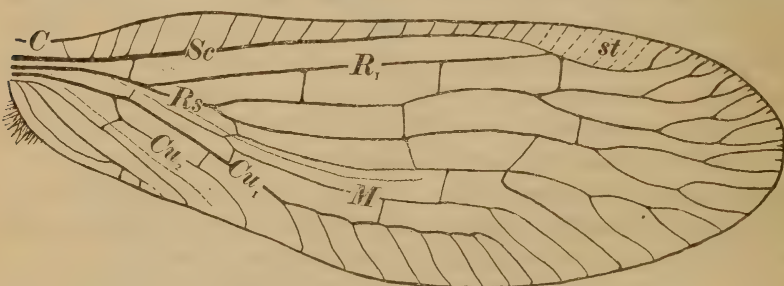


Fig. 35 Fore wing of Climacia dictyona Ndm

posteriorly and then anteriorly to the base of the wing, leaving the greater part of the costal area yellow. A triangular yellow spot on the fork of the median vein, its apex directed toward but hardly reaching the hind margin of the wing; from its proximal side a less distinct yellowish streak extends to the base of the wing on the hind margin. Veins black except where crossing the yellow areas. In the wider spaces there are distinct fuscous, longitudinal streaks midway between the veins.

Abdomen brownish, paler apically.

Saranac Inn N. Y. Common. June 18 to July 1, and Aug. 10 to 20.

Figures: wing, fig. 35; maxilla, fig. 34; labium, fig. 36.

1 Synopsis Neur. N. Am. p. 199.

**Larva.** Length 5.5 mm; greatest breadth of body exclusive of spines 1 mm.

Color yellowish to greenish, varying with the color of the sponge, obscurely marked with brown; a middorsal incomplete stripe, darkest on the thorax (where also is a lateral one each side), divided and more interrupted on the abdomen.

Antennae setaceous, very sharp pointed, a very little longer than the piercing mouth parts, 15-jointed, the two basal joints turgid, meeting at an angle, the other segments narrowly cylindric.

Mouth parts adapted for piercing and sucking the sponge substance; labrum and labium rudimentary; mandibles and maxillae developed as long, channeled, decurved stylets, which may be applied in pairs, or all four together.[1]

Body with two rows each side of dorsum of mostly trifurcate, trisetigerous tubercles; a pair of simple, unisetigerous tubercles on the ventral side of the eighth abdominal segment. 10th abdominal segment not setigerous; extensile, bearing the spinneret.

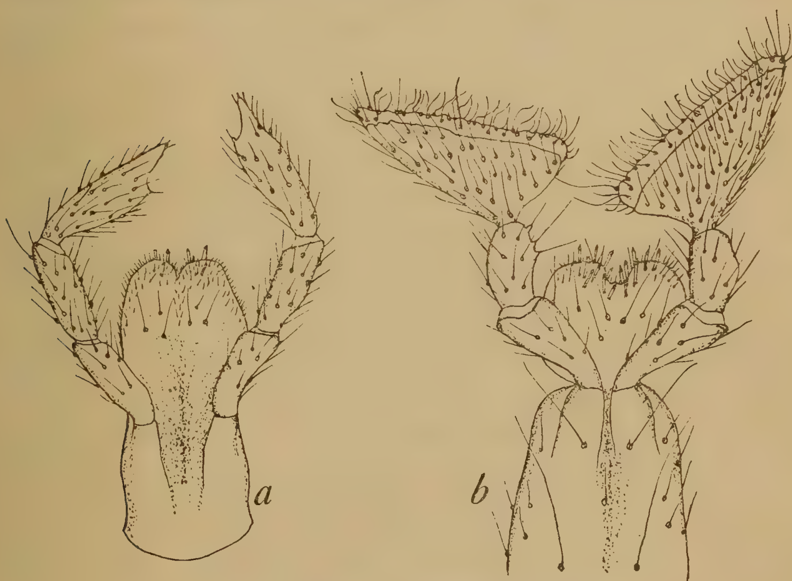


Fig. 36 Labia
*a* of Climacia dictyona Ndm
*b* of Sisyra umbrata Ndm

Very soon after my arrival at Saranac Inn, M. A. Roberts, a careful and observant employee of the Adirondack hatchery, called my attention to some minute, hemispheric, silken pupa cases, attached to the sides of the supply troughs in the hatchery building. There was an outer covering of coarse silk (pl. 12 fig. 4, 5) woven in hexagonal meshes, like bobbinet;

1 These are cast off, and the normal biting mouth parts developed during metamorphosis.

and there was an inner cocoon of finer threads closely woven. An examination of the contained pupa showed it to be a hemerobian. From some pupa cases stripped from the trough and placed in a vial plugged with cotton, I first bred on June 18 the species described above as Climacia dictyona n. sp. The same day I found my first specimen at large in one of the hatchery windows.

During the remainder of June the imagos of this species were fairly common. Then they disappeared, to reappear in some numbers about the middle of August. Whether this means another distinct brood I can not say, with certainty.

The larvae and pupae are very similar in form and in habits to those of Sisyra, described above. The cocoons are similarly located, and are often intermixed with those of Sisyra, but are much more beautifully and skilfully wrought. The imagos were taken a few times at trap lanterns, and in sweeping of aquatic vegetation, but the hatchery ceiling was the best collecting ground. The eggs were not found. The larvae, as in Sisyra, live on fresh-water sponges.

I could find none of these sponges in condition fit for determination; up to the time of leaving Saranac Inn no gemmules were developed on them. The commoner species, and the one on which larvae of both Sisyra and Climacia were observed, was probably Spongilla fragilis Leidy; for they appeared to be quite the same species as that on which I found Sisyra larvae at Lake Forest, and that was certainly S. fragilis. It was not without interest that I noted a striking difference in the behavior of this sponge in the two localities. At Lake Forest it grows on logs in a very shallow, exposed pond, which generally dries up about midsummer, leaving the logs exposed, usually to remain so for several months. There, gemmules were fully formed before the first of July. In the cool, deep, permanent water of Little Clear pond, however, where sponges were likewise abundant on the logs but not subject to exposure and evaporation, I could find no gemmules at all up to the time of my departure, August 20.

I would suggest that as a common name for the insects of these two genera, spongilla flies, or sponge flies, would not be inappropriate.

## Order TRICHOPTERA

### *Caddis flies*

BY CORNELIUS BETTEN

Insects of this order were found to be very abundant at Saranac Inn. Larvae and pupae were very common in Little Clear creek and along the edges of the lakes and ponds of the vicinity, while adults were taken in great numbers by the trap lanterns. Throughout the period of work, swarms of adults, mainly of three species, settled on the hatchery windows, having doubtless transformed in the fish troughs. While the material was therefore abundant, only four species were successfully reared. Of many species the time of transformation did not fall within the period of the work, and consequently a full life history could not be recorded.

The larvae of these insects, as is well known, build for themselves cases differing greatly in manner and material of construction. Several species of larvae were reared from the egg, and the larvae were observed to begin making their cases almost immediately after hatching. Before building their cases the young larvae are doubtless at the mercy of many enemies. Hydras were seen killing many of them in rapid succession but were unable to use them as food because of their size. The characteristic forms of the cases may be recognized almost from the beginning. The cases are enlarged as the growth of the insect demands. The food of the larvae is doubtless largely vegetable. Several species were observed feeding on stonewort, Nitella, and river weed, Potamogeton, which flourished in the creek. Some species are however known to be carnivorous in their habits.

Well protected by its case, the body of the caddis fly larva needs no hard covering of chitin. The head and the thorax, with the three pairs of legs, protrude from the case when the larva is moving about or feeding, and these parts are protected somewhat more than the other parts. The legs terminate in one-jointed tarsi, each of which has a single claw. A spur is very prominent at the base of each hook. The abdomen has nine well defined segments and an anal appendage terminated by a pair of hooks pointing outward. These hooks can be fastened into the sides of the case and thus prevent the forcible eviction of the larva. The dorsal side of the first segment is marked by a large protractile tubercle. Two smaller tubercles are located on the ventral side of the same segment. These tubercles are supposed to serve the larva as a means of maintaining its position in its case. This view is supported by the fact that a species of Hydropsychidae reared at Saranac Inn constructed no larval

case and had no tubercles on the abdomen. Numerous filaments on the abdomen serve as respiratory organs, obtaining oxygen from the water which is kept circulating through the case by the undulatory motion of the body.

When the time for transformation approaches, the larva closes the opening of its case, sometimes with the same material as that used in the case itself, but frequently with other things. Sometimes only a web of silk is spun across the opening, and in every case sufficient space is left for the circulation of the water. During the pupal period the cases are generally fastened to submerged sticks, stones or other supports. In size the pupa does not differ greatly from the larva. The eyes have become far more prominent. Wings and antennae appear and are folded backward and downward under the body. The legs and palpi are also folded beneath the body. In place of prolegs and hooks, two long tube-like processes (fig. 38) terminate the body. The pupa holds its position by means of hooks on the dorsal side. Generally there are hooks pointing backward at the anterior edge of several segments, while at the posterior edge of one or two segments is a pair of plates bearing spikes which point forward. The respiratory filaments remain, and breathing is doubtless accomplished by the same method as in the larval stage. When the time of transformation arrives, the pupa leaves its case, climbs up some support, casts its skin and emerges as an adult insect. Some species emerge directly from the surface of the water.

So far as observed, the adult caddis flies do not feed. They spend their lives near the place of emergence, most of them flying but little, at least during the day, but some species may be seen swarming just over the surface of the water. The large number taken by the trap lantern is evidence of the nocturnal habits of the adults. The laying of the eggs was not observed but must of course take place in or directly above the water. Many clusters of eggs were found under the bark of submerged trees, which would lead to the conclusion that in some cases the female insect goes under water to deposit the eggs. The circular cluster of greenish eggs shown in plate 33, figure 4 was found suspended on a submerged twig under a log floating in deep water. The number of eggs in this cluster was estimated at 450.

In the description of species given below, there was no opportunity for comparison with other work of the same kind. In fact, no descriptions of the immature stages of the American species of Trichoptera has heretofore been published, except the paper of Miss Cora Clarke[1] which

[1] Clarke, Cora H. Caddice worms of Stony brook. Psyche. 1891. p. 153.

deals chiefly with the cases and the habits of a few species. Two of those described by her seem to correspond with two described below, viz, Molanna cinerea Hag. and Polycentropus lucidus Hag. There have subsequently come to hand the very valuable papers of Prof. Klapálek[1] in which the cases, larvae and pupae of 53 European species are described. It is from these papers and from that of Dr Struck[2] that the following table for the determination, by families, of caddis fly larvae has been compiled. The undetermined species herein described have been arranged according to this table. I regret exceedingly that a closer determination has been impossible. The first three species discussed below were reared and subsequently determined from the adults. The fourth in the list was also reared. Its adult was sent to MacLachlan but no report of its identification has yet been received. I have found that adult characteristics are sufficiently evident in the pupae to admit of determination, to families, by the use of Banks'[3] table for adults.

For the identification of the adults herein listed, I am largely indebted to Mr Nathan Banks of Washington D. C. The drawings of the cases, larvae, pupae and adults are all by Mrs J. H. Comstock of Cornell university. I am indebted most of all to Dr J. G. Needham, under whose direction this work has been done.

### KEY TO FAMILIES OF CADDIS FLY LARVAE

*a* Larva larviform, i. e. with head bent downward at an angle with the body, tubercles generally present on the basal abdominal segment, gill filaments, when present, simple (except in some Limnophilidae), lateral fringe generally present.

*b* Hind legs not more than twice as long as the first pair.

*c* Head longitudinally elliptic, at slight angle with the body, pronotum only chitinized, abdominal constrictions deep, third pair of legs slightly longer than the first. *Cases* of vegetable matter laid longitudinally and forming a spiral, widening at the anterior end...Phryganeidae

*cc* Head oval to round, pronotum chitinized, mesonotum often, metanotum seldom chitinized, abdominal constrictions slight.

*d* Lateral fringe well developed; cases various.....Limnophilidae

*dd* Lateral fringe slightly developed, cylindric case of sand or small stones.......................................Sericostomatidae

*e* Three tubercles

[1] Klapálek Fr. Metamorphose der Trichopteren, Archiv der Naturwissenschaftl. Landdurchforschung von Böhmen 6, Band No. 5 and Band 7, No: 6.

[2] Struck, R. Neue und Alte Trichopteren-Larven-gehäuse. Illus. Zeits. Ent. Bd 4. No. 8, 10, 13, 17, 19, 21, 22.

[3] Banks, Nathan. A synopsis, catalogue, and bibliography of the Neuropteroid insects of temperate North America. Am. ent. soc. Trans. 1892. 19:338.

*f* Tubercles low and broad, pronotum quadrilateral, claws with two basal hooks.......Sericostoma, Oecismus, Notidobia

*ff* Tubercles conical, pronotum transversely elliptical
Goëra, Silo, Lithax

*ee* No dorsal tubercle

*f* No lateral tubercles
Brachycentrus, Oligopletrum, Micrasema

*ff* Lateral tubercles present
Crunoecia, Lepidostoma, Lasiocephala

*bb* Hind legs more than twice as long as the first pair, abdominal constrictions slight, cylindric case of sand and small stones........Leptoceridae

*aa* Larva campodeiform, i. e. with head in line with the main axis of the body, tubercles and lateral fringe wanting, gill filaments, when present, branched

*b* Abdomen little, if any, thicker than the thorax

*c* Third pair of legs about the same length as first pair, no portable larval case.............................................Hydropsychidae

*cc* Third pair of legs a little longer than the first. No larval cases
Rhyacophilidae

*bb* Abdomen much thicker than the thorax: case kidney shaped, of small stones, or flat and parchment-like ......................Hydroptilidae

## SPECIES REARED AT SARANAC INN

### Molanna cinerea Hagen

Plate 13, figures 1–6

1861 Molanna cinerea Hagen, Synopsis Neur. N. Am. p. 276

1892 Molanna cinerea Banks, Am. ent. soc. Trans. 19:366 (listed)

**Habitat.** Larvae and pupae were found in great abundance on sand bottoms with little or no vegetation. Adults rest on vegetation or other support near the place of emergence, their appearance, specially their position (pl. 13, fig. 5), with antennae laid flat on support, wings and abdomen elevated, causing them to be easily mistaken for small snags.

**Occurrence.** Abundant throughout the period of work.

**Case.** (Pl. 13, fig. 6) Flat case of sand and very fine stones. Rounded at both ends. Forward end extended on dorsal side, forming a protection to the larva even when reaching out of its case. Length 20 mm. Greatest width of 10 mm near the forward end.

**Larva.** (Pl. 13, fig. 1–2) Length 12 mm. Width 2 mm. The head, prothorax, and mesothorax are light brown or yellowish. Metathorax and abdomen are light green. A black Y-shaped line extends over the head and prothorax, the arms of the Y running from the corners of the mouth and joining at the rear of the head. The pedicel of the Y extends over the

prothorax. Another black line incircles the head and prothorax, running through the base of the Y, passing obliquely downward to the gula which is of the same color. The mesothoracic shield is spotted with black and brown. The legs are light brown, the coxa, trochanter, and proximal part of the femur being margined with black. The first and second pairs of legs each have one prominent spur on the tibia. The third pair of legs is more slender and hairy than the others, and the tarsi are terminated by small, feathery brushes instead of hooks. Two rows of respiratory filaments occur on the dorsal, and two on the ventral side. The number of filaments issuing at the same spot on the dorsal side is 0, 4, 4, 4, 3, 2, 2, 0, 0, and on the ventral side 0, 3, 3, 3, 2, 2, 0, 0, 0, the figures representing the segments in order. These filaments are placed at the anterior margins of the segments. The hooks terminating the body are supported on two-jointed prolegs.

**Pupa.** (Pl. 13, fig. 3) Length 12 mm. Width 2 mm. Antennae 10 mm. Wings 7 mm. Head and thorax white; abdomen pink or green. Two black lines run the length of the body both above and beneath. Respiratory filaments persist on both dorsal and ventral sides. The lateral fringe which forms a loop under the eighth segment is composed of soft black hairs. The spurs on the tibiae, which appear as feathery brushes, number 2, 4, 4 on the first, second and third pairs of legs respectively. Hooks pointing backward occur in two rows on the dorsal side of the third, fourth, fifth and sixth segments at the anterior edge of the segments. Two plates with spikes pointing forward are at the posterior edge of the fifth segment.

## Polycentropus lucidus Hag. ?

Plate 13, figures 7–11

**Habitat.** Larvae and pupae were found in sandy bottoms with little or no vegetation. Adults were commonly found resting on vegetation in the creek and on the side of the hatchery near the stream.

**Occurrence.** Abundant throughout the period of work.

**Case.** (Pl. 13, fig. 10) Very soft tubular case of fine sand. It is frequently branched and where the insect lies has two distinct layers. The tube is much longer than the larva and is not portable. The position of the larva or pupa is readily recognized. They lie in a part of the case twice the diameter of the rest of the tube.

**Larva.** (Pl. 13, fig. 7) Length 14 mm. Width 2 mm. Head yellow; prothorax yellow with black line incircling its rear margin. The

remainder of the body white; legs yellow with black line extending backward from the coxa of the second and third pairs of legs over the mesothorax and metathorax respectively. No respiratory filaments, tubercles or lateral fringe are present. The terminal hooks are each supported on a very long two-jointed proleg.

**Pupa.** (Pl. 13, fig. 8) Length 12 mm. Width 2 mm. Antennae 7 mm. Wings 4 mm. Head and thorax yellowish white; antennae and legs yellow; abdomen pinkish with slightly darker band on the middle of the dorsal side. A single respiratory filament occurs on each side of the first segment. A pair of filaments occur in similar position on the second, third and fourth segments. The hairy tibial spurs on the legs, are 3, 4, 4 on the first, second and third pairs respectively. The body ends in two blunt, hairy, appendages of two lobes each. Hooks pointing backward occur in two rows on the dorsal side of the third, fourth, fifth, sixth and seventh segments at the anterior edge. Two plates with spikes pointing forward are found at the posterior edge of the fifth segment.

**Eggs.** Eggs of this species laid by an adult which was bred, are shown in plate 13, figure 11.

### **Hydropsyche** species? (near phalerata Hag.)

Plate 15, figures 1-4, 7

**Habitat.** Larvae and pupae found in rapid currents in Little Clear creek. Adults settled in great numbers on the hatchery windows.

**Occurrence.** Abundant throughout the period.

**Case.** No larval case, only strands of silk between the rocks. Pupal case (pl. 15, fig. 4) of rather coarse stones fastened to larger stones or other supports.

**Larva.** (Pl. 15, fig. 3) Length 16 mm. Width 3 mm. Head brownish yellow. A dark brown patch in front, and in the center of this, a horseshoe shaped, yellow mark opening posteriorly. Labium almost black. Prothorax brownish yellow margined with black. Mesothorax same except that the black margin is not complete. Instead, there is a semicircular black line at posterior margin. Mesothorax is similar with black spot instead of the semicircle. Legs yellow with white spots on coxa and femur. Abdomen white, the dorsal side thickly set with blunt, brown hairs. No tubercles on the first segment. Filaments occur only on the ventral side. They are set in two rows on the mesothorax, the

metathorax and the first seven segments of the abdomen. Two stalks occur together on each side of the segment, and these are in turn divided into six or nine filaments. Instead of four stalks the mesothorax has two, the metathorax three and the seventh abdominal segment one. Two brown spots are very prominent on the ventral side of the eighth and of the ninth segments. The anal hooks are on very large prolegs of one joint each. A bunch of hairs is at the base of each hook. One or two stout hairs arise near the base of the hook and extend to meet its point.

**Pupa.** Length 11 mm. Width 2 mm. Head pinkish. Thorax white. Spurs on the tibiae arranged in the order 1–4–4. Abdomen white with brick red on the dorsal side. Hooks pointing backward are on the third, fourth, fifth, sixth, seventh and eighth segments. Plates with spurs pointing forward are on the third and fourth segments. I was able to make out but eight abdominal segments in this pupa.

### 1 **Halesus** species?

Plate 32, figures 3, 6; plate 33, figure 3

**Habitat.** Larvae and pupae were found in Little Clear creek and along the shore of Little Clear lake, specially on wood strewn bottoms.

**Occurrence.** Larvae were quite plentiful during the entire period. Pupae were obtained only at the last. Only two or three adults were seen and those during the last week of work. A single specimen of this species was bred Aug. 31, 1900.

**Case.** (Pl. 33, fig. 3) Case of thin pieces of wood placed at right angles to the length of the case with their ends crossed. The coarseness of the material used varies but is uniform for each case. Length 18 to 20 mm. Width 7 mm.

**Larva.** (Pl. 32, fig. 3) Length 15 mm. Width 4 or 5 mm. Head brownish black with broad white stripes running obliquely from the corners of the mouth along both dorsal and ventral sides of the eyes. There is a white spot where the inner pair of stripes would unite if continued. The anterior half of the dorsal side of the prothorax is black, the posterior half white. The mesothoracic shield blackish brown bordered with black. Metathorax yellow with large brown spots. Legs yellow with triangular white spot on the outside of each femur at its joint with the tibia. Two spurs on each tibia. Abdomen purplish, whiter beneath. Anal hooks are on

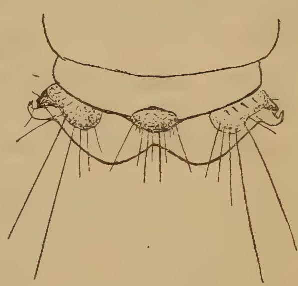

Fig. 37 Dorsal view of end of abdomen of larva

single jointed prolegs. The position and number of respiratory filaments may be represented diagrammatically.

| | Dorsum | | | | Venter | | | |
|---|---|---|---|---|---|---|---|---|
| 1 | | | | | | | | |
| 2 | 3 | 3<br>3 | 3<br>3 | 3 | 3 | 3<br>3 | 3<br>3 | 3 |
| 3 | 3<br>2 | 3<br>3 | 3<br>3 | 3<br>2 | 3 | 3<br>3 | 3<br>3 | 3 |
| 4 | 2 | 2<br>2 | 2<br>2 | 2 | 2 | 3<br>3 | 3<br>3 | 2 |
| 5 | 1 | 2<br>2 | 2<br>2 | 1 | 1 | 3<br>3 | 3<br>3 | 1 |
| 6 | | 2<br>2 | 2<br>2 | | | 2<br>2 | 2<br>2 | |
| 7 | | | | | | 2<br>1 | 2<br>1 | |
| 8 | | | | | | | | |
| 9 | | | | | | | | |

**Pupa.** (Pl. 32, fig. 6) Length 16 to 18 mm. Width 4 to 5 mm. Antennae as long as the body. Wings 10 mm. Head yellow, thorax white. Spurs on the tibiae occur in order 1–3–3. Abdomen white with dull brick red on the dorsal side, specially on the anterior segments. Filaments are also of a dull brick red color. Hooks pointing backward are on the third, fourth, fifth and sixth segments. Plates with spikes pointing forward are at the posterior edge of the fifth segment.

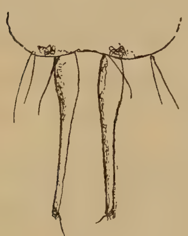

Fig. 38 Caudal processes of the pupa

**Eggs.** The eggs of this species are laid in a compact cluster with abundant gelatin. A cluster of about 300 eggs was kept till the larvae hatched and their identity was shown by the characteristic cases they made.

## OTHER LARVAE FOUND AT SARANAC INN

(ARRANGED BY FAMILIES)

## LIMNOPHILIDAE

### 2 Halesus species?

Plate 32, figure 2 and 5; plate 33, figure 2

**Habitat.** Larvae and pupae found in Little Clear creek. The pupae are commonly fastened to submerged tree branches closely resembling broken twigs.

**Occurrence.** Larvae common throughout the period. Pupae not found till the very last.

**Case.** (Pl. 33, fig. 2) Case of irregular pieces of wood placed longitudinally with slender stick extending beyond the posterior end. Length 23 mm. Width 8 mm. Length of stick beyond the case about 19 mm.

**Larva.** (Pl. 32, fig. 2) Length 18 mm. Width 4 mm. Head, prothorax and mesothorax reddish brown with a pattern of black spots. Mesothorax has right angled black lines in the posterior corners. Metathorax is yellowish brown. Legs brown, margined with black. Spurs on the tibiae arranged in order 2-2-2. Abdomen whitish with red patch on the dorsal side. Respiratory filaments occur with or near the divisions between the abdominal segments. Beginning at the division between the first and second segments, they occur in the following order on the dorsum, 0, 0, 3, 3, 2, 1, 0, 0, 0. On the ventral side their arrangement is 0, 0, 3, 3, 3, 2, 2, 1, 0. Anal hooks are on two-jointed prolegs.

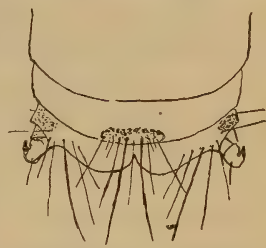

Fig. 39 Dorsal view of end of abdomen of larva

Fig. 40 Lateral fringe of an abdominal segment of the larva

**Pupa.** (Pl. 33, fig. 5) Length 19 mm. Width 4 mm. Antennae 16 mm. Wings 8 mm. 3 ocelli. Head reddish yellow. Thorax and legs yellow. Spurs on the tibiae arranged in order 1, 3, 3. Black spines numerous on the legs. Abdomen white with reddish brown above and yellow beneath. Heavy black fringe along the rear four segments. Hooks pointing backward on the anterior edge of third, fourth, fifth, sixth and seventh segments. Plates with spikes pointing forward at the posterior margin of fifth segment. Respiratory filaments remain.

### 3 Halesus species?

Plate 32, figures 3 and 6; plate 33, figure 3

**Habitat.** Larvae and pupae found in Little Clear creek.

**Occurrence.** Larvae quite common throughout the period. Pupae found only during the last four days of the session.

**Case.** (Pl. 33, fig. 3) Cylindric case of wood and sand or small stones, often finely colored. Length 24 mm. Width 6 mm.

**Larva.** (Pl. 32, fig. 3) Length 16 mm. Width 4 mm. Fewer black spots on head but otherwise same as larva just described. The length of the pupae of this species would seem to indicate that the larvae taken were not full grown.

**Pupa**. (Pl. 32, fig. 6) I could distinguish no difference between this and the pupa just described.

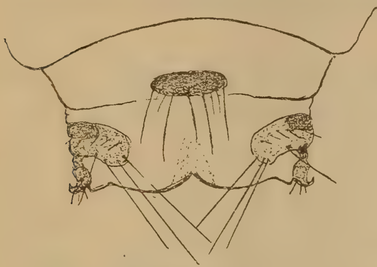

Fig. 41 End of abdomen of larva

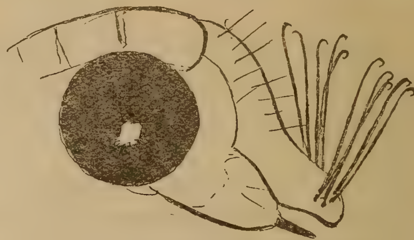

Fig. 42 Head of pupa, showing "moustache"

## 4 Halesus species?

One specimen found.

**Case.** This larva was found among some of no. 3 of this genus and presumably was accidentally placed there because of similarity of case.

**Larva.** Length 18 mm. Width 5 mm. Head, prothorax and mesothorax yellowish brown spotted with black. Mesothorax has a black mark like that of no. 1 and 2. Abdomen white with brick red on dorsal side. Legs have white spot on the outside of the femur at the joint with the tibia. A white dot occurs at the anterior edge of each half of the third, fourth, fifth, sixth and seventh segments. Anal hooks are on two-jointed prolegs. The respiratory filaments occur in position and number indicated in the diagram.

| | Dorsum | | | | Venter | | | |
|---|---|---|---|---|---|---|---|---|
| 1 | | | | | | | | |
| 2 | 2 | 3 | 3 | 2 | | 3 | 3 | |
| | 2 | 3 | 3 | 2 | 3 | 3 | 3 | 3 |
| 3 | 3 | 3 | 3 | 3 | | 3 | 3 | |
| | | 3 | 3 | | 2 | 3 | 3 | 2 |
| 4 | 2 | 3 | 3 | 2 | | 3 | 3 | |
| | | 3 | 3 | | 2 | 3 | 3 | 2 |
| 5 | 1 | 2 | 2 | 1 | | 3 | 3 | |
| | | 2 | 2 | | 2 | 2 | 2 | 2 |
| 6 | | 2 | 2 | | | 2 | 2 | |
| | | 2 | 2 | | 2 | 2 | 2 | 2 |
| 7 | | 2 | 2 | | | 2 | 2 | |
| | | 2 | 2 | | 1 | 2 | 2 | 1 |
| 8 | | 1 | 1 | | | | | |
| 9 | | | | | | | | |

### SERICOSTOMATIDAE

#### 1

One specimen taken from hatchery trough June 19, 1900.

**Case.** Cylindric yellow case slightly curved, composed mainly of silk with multitudes of spicules of fresh-water sponge. Length 10 mm. Width tapers from 3 at the anterior end to 2 mm. at the posterior end.

**Larva.** Length 8 mm. Width 1.5 mm. Head and thorax light yellow. Lines of black chitin over each side of the mesothorax and also on the dorsal side of the first segment, extending obliquely over the lower tubercles. Numerous respiratory filaments occur on the second, third, fourth, fifth, sixth and seventh segments both above and below. The anal hooks are supported on two-jointed prolegs.

#### 2

One specimen taken from hatchery trough June 19, 1900.

**Case.** Length 8 mm. Tapers from 3 to 1 mm. in diameter. Composed of small pieces of wood or bark and is of a straight cylindric shape.

**Larva.** Length 7 mm. Width 1 mm. Head and prothorax yellowish brown with numerous lighter dots. Mesothorax and metathorax white. A black line curved outward is on each half of the dorsal side of the mesothorax. Black line on margin of each coxa. In case of the second and third pairs of legs this line extends nearly to the rear margin of the mesothorax and metathorax. Abdomen white. On the first abdominal segment a black line runs from the rear of the segment downward to the top of the lower tubercles. Numerous small filaments occur on the second, third, fourth, fifth, sixth and seventh segments on both dorsal and ventral sides. The two two-jointed prolegs each supports a single large hook with a smaller one at its base.

### LEPTOCERIDAE

#### 1

One specimen taken June 19, 1900.

**Case.** Cylindric case of bark slightly curved. Length 11 mm. Width 1 mm. A slender piece of light colored wood is fastened along one edge, extending two or three mm beyond the case at each end, and a rectangular piece of wood is fastened to the case at the rear end on the side opposite the slender stick.

**Larva.** Length 7 mm. Width 5 mm. Head and thorax yellowish white with a pattern of dark brown spots. The legs are long and slender. Abdomen is white. The ninth segment is incircled by a row of spines pointing backward. There are no respiratory filaments. The two single-jointed prolegs each have four hooks.

### CASES FOUND WITHOUT LARVAE OR PUPAE

1

Case composed of pieces of wood 7 mm long placed lengthwise in a spiral band. This case has three complete turns of the band. Diameter tapers from 8 to 6 mm. Found in Little Clear creek July 14, 1900. This case was evidently of a Phryganeid larva.

2

Slightly curved cylindric case of very fine sand. Length about 15 mm. Diameter decreases from 3 to 2 mm. Found in very great abundance in Bone pond.

3

Tubular case, slightly curved, composed mainly of silk closely woven with some material resembling the bark of young twigs, having a yellow appearance within and brownish black without. Length 15 mm. Diameter decreases from 3 to 2 mm. Found in hatchery trough June 19, 1900.

4

Cylindric case of small pieces of wood. A large, flat, rectangular piece of wood 10x12 mm is beneath the forward end. A long round piece runs along the upper side. Length of this piece 10 mm; diameter 2 mm. The case proper measures 10 mm, with a diameter of from 4 to 6 mm.

5

Case of hemlock leaves fastened by their bases. The other ends stand out obliquely from the case. Length 17 mm. Diameter 8 mm.

6

Cylindric case made of silk with bits of bark; a hemlock leaf lies flat on each side of the case. Length 11 mm. Width 2 mm.

### LIST OF ADULT CADDIS FLIES FOUND AT SARANAC INN

#### Phryganeidae

Phryganea cinerea Hag. (pl. 30, fig. 1) August 5
Phryganea vestita Walk. July 25
Neuronia dossuaris Say. August 10
Neuronia postica Walk. July 16

### Limnophilidae

Limnophilus ornatus Banks July 18
Goniotaulius dispectus Walk. ? (pl. 30, fig. 2) August 8
Goniotaulius pudicus Hag. July 18
Halesus indistinctus Hag. (pl. 30, fig. 3) August 14
Halesus hostis Hag. (pl. 31, fig. 1) July 30
Stenophylax scabripennis Ramb. July 22
An undetermined Limnophilid. August 20

### Leptoceridae

Molanna cinerea Hag. (reared) (pl. 13, fig. 1–6) July 6 to August 20
Triaenodes ignita Walk. (pl. 34, fig. 2) July 16, 18
Leptocerus *species?* August 4
Leptocerus *species?* (*near* flaveolata) June 29, July 7
Leptocerus resurgens Walk. (pl. 34, fig. 1) July 2, August 8
Mystacides nigra Linn. August 1

### Hydropsychidae

Hydropsyche scalaris Hag. (pl. 34, fig. 3) July 3, August 12
Hydropsyche *species? near* phalerata (reared) (pl. 15, fig. 1–4) July 5, August 14
Polycentropus lucidus Hag? (reared) (pl. 13, fig. 7–11) July 7 August 19

### Rhyacophilidae

Chimarrha aterrima Walk. July 15, 19
Chimarrha *species?* July 18

### Order DIPTERA

Of this immense group a considerable part is aquatic. That part is abundantly represented at Saranac Inn, but did not receive a fair measure of attention. Dipterous larvae, comparatively speaking, are somewhat better known than are the immature stages of the "lower" orders to which we gave our principal attention. Only those Diptera which in their immature stages were most accessible, or seemed likely to yield new or interesting forms, were studied. Below is an annotated list of the groups which came more or less under observation.

*Tipulidae*—Crane flies. Abundant in individuals, representing a considerable number of species. No attempt was made to determine the few specimens collected, save the giant Tipula abdominalis Say, whose larva is described below. A small species with beautifully spotted wings was bred from a floating pupa, but the single, imperfect, alcoholic specimen is insufficient for description. During the month of

July numerous pupal cases of an unknown species were seen sticking out between the boards which covered the bank of the creek beside the hatchery. Many larvae and pupae of the singular Bittacomorpha clavipes were collected from the rotting vegetation in little shallow bays in the borders of Little Clear creek, where they were very abundant; the imagos were seen commonly, also, gliding slowly along through the air with a singularly phantom-like appearance and motion. The few that retained their six caducous legs after pinning are in the state collection at Albany.

*Chironomidae* and *Culicidae*—gnats, mosquitos, midges, etc. These families were abundantly represented, and a goodly number of species were reared, but, unfortunately, there has not been opportunity for the preparation of descriptions in time for incorporation into this report.

*Mycetophilidae*. During the last days of our session the large Asindulum montanum Roeder was common in the hatchery windows.

*Simuliidae*. The single, unobtrusive species, S. venustum Say, was very common; during the earlier part of our session the hatchery windows, specially the windows nearest the inflow pipes, swarmed with them. Some new observations on the oecology and habits of the black fly in its earlier stages are recorded on pages 407–8 and illustrated in plate 15, figures 9–11, 18–20.

*Stratiomyiidae*. Soldier flies. But few specimens were taken belonging to this family. These belonged to two very interesting species, one to our largest and handsomest, Stratiomyia badius Walk., whose larva is described on page 576; and the other, one of the smallest members of the family, representing a new genus and species, is described below by D. W. Coquillett, and named by him Zabrachia polita.

*Empididae*. A new genus and species was found in its immature stages associated with Simulium in rapids and reared: it is described below by Mr Coquillett as Roederiodes juncta. Hilara mutabilis Loew was common about the shores of Lake Clear during the last week in June. Little companies would start before one's feet when approaching the edge of the water, disperse and settle again near by.

*Sciomyzidae*. Two interesting swale flies, Sepedon fuscipennis Loew and Tetanocera pictipes Loew, were reared in large numbers. Their larvae and pupae are figured and described herewith. These were from below the hatchery on Little Clear creek. Above the hatchery, nearer the railroad in the natural meadow beside the water, were collected, while sweeping, several additional species of Tetano-

cera, whose immature stages were not observed: T. boscii Desv. T. saratogensis Fitch, and T. clara Loew.

*Ortalidae.* All along the above mentioned creek the handsome fly, Melieria (Ceroxys) similis Loew, was very common in the grass; it was always abundantly represented in sweepings. Its immature stages were not observed.

*Tabanidae.* These should be mentioned if only for their abundance. We collected quite a number of species from the hatchery windows; we obtained many larvae but did not undertake to rear them; all these were sent, undetermined, to the state collection.

*Conopidae* and *Bombyliidae.* It may be worth while mentioning that the splendid wasp-mimicker, Physocephala furcillata Will, was a very common insect on the flowers of thistle and goldenrod, and that a number of species of bombyliids flitted in numbers along every roadside and path through the forest.

## **Tipula abdominalis** Say

Plate 35, figure 2

1823 Tipula abdominalis Say, Acad. nat. sci. Phil. Jour. 3:18 (The original description is excellent.)
1828 Ctenophora abdominalis Wiedmann, Aus. zweifl. ins. 1:37
1848 Tipula albilatus Walker, List dipt. ins. Brit. mus. 1:65
1859 Ctenophora abdominalis Leconte, Complete writings T. Say, 2:45
1878 Tipula abdominalis Osten-Sacken, Cat. Dipt. N. Am. p. 37 (listed)
1900 Tipula abdominalis? larva, Johnson, Ent. news. 11:578 (note)

This giant crane fly was not raised. It was common about the hatchery during August, and the workmen, impressed by its great size and sprawling attitudes, frequently brought in specimens picked from the sides of the building. In the borders of the creek back of the hatchery were found numerous tipuline larvae so large they could hardly belong to any of our species except this one. They certainly could not be the larvae of any other species we found at Saranac Inn. Therefore, I have referred them by supposition to this species, and give herewith a description and figures.

These larvae were associated with Bittacomorpha clavipes in shallow bays filled with red-rotten trash in the edges of the creek, various sizes from half grown to full grown occurring together. Pupae were not found.

**Larva.** Pl. 36, fig. 1, 2. Length 51 mm; diameter 6 mm.

Body cylindric except at ends, tapering anteriorly on the thoracic seg. ments, a little less narrowed on the two posterior segments abdominal

Head retracted within the prothorax, only the blunt tips of the antennae showing at the sides.

Color greenish brown, darker toward the head and on the dorsum of the penultimate segment, paler on the ventral surface, and most transparent on the sides of the body.

Each of the middle abdominal segments has a secondary transverse groove at two thirds its length, and on its posterior third a transverse line of setigerous tubercles, from which another line extends anteriorly at the sides of the dorsum; the seta at the posterior end of this lateral row is much longer than any of the other setae. The yellow color on these setigerous ridges forms the basis of the color pattern, which consists elsewhere of multitudinous spots that are mainly arranged symmetrically in pairs.

Anal prominence pale yellowish, bearing at its sides three pairs of similar, equal appendages, each about as long as the greatest diameter of the body. The respiratory disk bears three pairs of marginal lobes or teeth, and, between the base of the lowermost or ventral pair and the anal prominence, a conspicuous, setigerous tubercle. The six marginal lobes are all blunt at the apex, where they bear a few, fragile hairs, and are covered except on the posterior face with a close, brownish pubescence. Paired black lines extend up the posterior face of each lobe, and at the base of these lines there is, on each lobe of the lowermost pair, a pair of black spots. Between the brown, cup-shaped, spiracular openings there is a pair of black marks.

Saranac Inn, Little Clear creek, July and August 1900.

## **Stratiomyia badius** Walker

Plate 35, fig. 1

1849 Stratiomyia badius Walker, List dipt. ins. Brit. mus. 3:529

1849 Stratiomyia ischiaca (Harr.) Walker, List dipt. ins. Brit. mus. 3:529

1866 Stratiomyia picipes Loew, Centur. 7:21

1878 Stratiomyia picipes Osten-Sacken, Cat. Dipt. N. Am. p. 48 (listed)

1895 Stratomyia badius Johnson, Am. ent. soc. Trans. 22:243 (a full description)

This fine soldier fly was not uncommon along the railroad track east of the Saranac Inn station on small clumps of goldenrod during August. On August 12 Dr O. S. Westcott and I collected a few, finding them associated with the wasp-mimicking conopid, Physocephala furcillata Will., and wasps of many species and cerambycid beetles. The flower clumps were rather few and small, and collecting from them was excellent.

A single stratiomyiid larva was taken during the season. It clearly belonged to the genus Stratiomyia, of which this was the only species observed.

**Larva**. Length of body 27.5 mm, caudal tuft of plumose hairs 2 mm additional; greatest diameter (across base of abdomen) 4 mm; width of head 1.7 mm. Color uniform blackish.

Head depressed, in outline conic as seen from above; mouth parts inserted in a rectangular notch at its anterior end, the hind margin of the notch straight or nearly so; from the hind angles of the buccal notch there extends posteriorly on the top of the head a pair of grooves, parallel or a little convergent for two thirds of their length, where connected by a transverse groove, thereafter divergent toward the hind angles of the head; the depth of the buccal notch equals one fourth of the length of the head: the sides of the head are rugulose. The head bears setigerous punctures as follows: a pair on the hind angles of the buccal notch, a pair posterior to these between the grooves, a postocular pair, and a subocular pair, and two pairs still lower on the sides of the head.

The anterior third of the thoracic segments (which become successively wider from the front) is closely beset with whitish recurved hairs, which disappear on the foremost abdominal segments; there are a few long straight hairs at the lateral margins of all the body segments excepting the the last, which bears on its lateral margins a line of pubescence. Hairs of caudal circlet plumose their whole length, yellowish with a blackish tinge just beyond the base.

This larva differs from that of Str. norma Wied. as figured and described by Hart[1] farther, in that the prothorax is longer than meso or metathorax, the anal groove on the ventral side of the caudal segment is closed and obsolete for the greater part of its length, only the T-shaped anterior third of it remaining; there are no paired markings beside it, and there are no grooves on the ventral side of the two preceding segments.

Stratiomyia seems to differ as a larva from Odontomyia, in the squarely cut hinder margin of the buccal cleft, in the absence of ventral hooks from the apices of the penultimate and antepenultimate segments as well as in the greater elongation of the last segment indicated by Hart.

A single larva was obtained from the surface of Little Clear creek back of the hatchery building July 27, 1900. It was an old larva, perhaps in transformation to puparium. A younger larva would probably have shown something more of color pattern; structural characters, however, should be as described.

During the last fortnight of our session a few specimens of a minute soldier fly were picked from the hatchery ceiling, where at first they were mistaken for Simulium, till a more careful glance discovered their rotundity of outlines. These proving to be new to science, D. W. Coquillett has, at our request, prepared the descriptions given on p. 585.

## Sepedon fuscipennis Loew

Plate 14, fig. 1–8

1859 Sepedon fuscipennis Loew, Wiener ent. monatschr. 3:299
1862 Sepedon fuscipennis Loew, Monographs Dipt. N. Am. 1:124
1878 Sepedon fuscipennis Osten-Sacken, Cat. Dipt. N. Am. p. 178 (listed)

This species is reported in Osten-Sacken's catalogue from the middle states. There are specimens of it in the Museum of comparative zoology

[1] Ill. lab. nat. hist. Bul. 4:249–52, pl. 14, fig. 57.

from the District of Columbia, from Cambridge Mass. and from Norway Me. It was quite common at Saranac Inn in Little Clear creek, in places where the creek flows through beds of bur reed, Sparganium, intermixed below the surface of the water with river weed, Potamogeton, and algae.

The flies sit on the erect burred leaves, with wings laid flat on their backs, their long hind legs folded together, the tip of the abdomen sloping down and nearly touching the leaf and the head lifted up high above it, in quite a froglike attitude. They fly but little—that little rather poorly—sweeping betimes, from one resting place to another near by. They rest on the leaves head downward more often than otherwise; I have frequently seen them sitting thus, close to the surface of the water, and apparently feeding on the stuff which collects about the bases of the leaves just above the water line.

Nothing has been written concerning the life histories of any of our few American species. When, in the course of a quantitative study of a little section of the creek border, I first noticed the singular pupae, after handling them for half an hour and throwing a number aside, having mistaken them for floating seeds (see pl. 14, fig. 4 and 6), and when I found also the larvae, likewise floating, exhibiting a muscid anterior and a tipuloid posterior end, and hook-bearing, dorsal prolegs for crawling beneath the surface film, I was sure I had found something of which I had read no account, and something it would be worth while to raise, if possible. So I stocked several of my floating cages (fig. 1) with larvae and pupae.

When imagos had emerged and had been determined, I found in Brauer's list of the described transformations of Diptera[1] that immature stages were known for two European species of the genus: S. sphegius and S. spinipes; but I have not been able to find the paper in which these are described[2].

**Larva.** (Pl. 14, fig. 1, 2.) Length full grown 11–12 mm; greatest diameter 2 mm.

Color yellowish or greenish brown of varying depth in different specimens, with tracheae showing through the thin integument more or less distinctly.

Body cylindric, strongly tapering anteriorly from the second abdominal segment, slightly tapering on the upturned posterior end behind the seventh abdominal segment; skin granular; head segment minute, blackish, retractile within the prothorax; the thoracic segments strongly retractile and protrusible, almost telescopic; mesothoracic twice as long, and meta-

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[1] Brauer, F. (Syst. studien Dipt. larv.) Denkschr. math-nat classe k. acad. wiss. Wien. 1883. 47:1–100, 5 plates.

[2] Gerke. Vehr. d. nat. unterhalt. Hamburg 1876. 3:145, pl. 3.

thoracic three times as long as the prothoracic segment, smooth except for a single piliferous tubercle each side.

Abdominal segments 1–7 similar, and of nearly equal length, each bearing three rings of tubercles, a median ring of tubercles of moderate size, and at each end close beside the suture separating the segments a ring of minute tubercles; median ring, with the pair of tubercles beside the middorsal line (pl. 36, fig. 3*a*) very mobile, transversely elongated, bearing a stiff brush of recurved or hooked bristles, well adapted for crawling beneath the surface film; on the ventral side, two pairs of prominent rounded tubercles; between the dorsal and the ventral there are on either side four or five lesser tubercles, mostly unisetigerous, sometimes not very distinct, the third of them, counting from above, a little out of line, in advance of the others. There is a broad median ventral lobe on the eighth abdominal segment, liplike rounded, covered with very minute recurved prickles.

Apex of the abdomen (pl. 36, fig. 3*b*) upturned, flattened, tipuloid, fashioned into a disk which surrounds the fringed respiratory apertures. There are two pairs of long processes on the ventral half of the margin of the disk and three pairs of low tubercles on the dorsal half of it. The two submedian ventral processes are long, triangular, almost lanceolate, simple; those of the pair external to these are two-jointed, the joint midway their length; both pairs are pilose, and about equal in length to the diameter of the disk. Respiratory apertures in two groups of three each, slitlike, radiating in arrangement. From the notches between the apertures and at their sides arise tufts of black, floating filaments arranged in a flat whorl, well adapted to holding the breathing apertures up to the surface of the water; these filaments are black, dichotomously (often irregularly) four or five times branched, about 10 or 12 in number, and extending almost to the margin of the disk.

The larva when undisturbed lies quietly at the surface of the water amid a tangle of vegetation. It can swim when disturbed, and its swimming is most curious. It pulls itself below the surface, turns over on its back, and then progresses by bending and straightening its body, striking the water sharply with the flat face of its caudal disk.

**Puparium.** (Pl. 14, fig. 3–5). Length 6 mm; greatest horizontal diameter 3 mm; vertical diameter 2.5 mm.

Color reddish brown, closely marked with yellowish on the ventral side. Body shaped like an undetermined seed, which was not uncommon, floating on the surface of the creek. I first mistook the pupae for seeds, and afterward occasionally mistook seeds for pupae, so good was the resemblance.

Body ovate, dorsally flattened and ventrally rounded, broadly canoe-shaped, but suddenly contracted anteriorly into a flat, truncate, rostral prominence .5 mm wide and .9 mm long. There is a black, middorsal curved mark (concave anteriorly) just behind the base of this beak. (When the imago emerges, this beak splits down its sharp lateral margins, and across the dorsum of the body near to the aboved mentioned black mark, and comes off as one half of the cap.)

The posterior end is suddenly, and strongly contracted into a cylindric tail, which is directed upward at an angle of 75° with the axis of the body. The float of the larva persists on the summit of this tail, and

doubtless continues functional. The fleshy processes and tubercles which surrounded the float in the larva are withdrawn anteriorly in the pupa and flattened down against the sides of this taillike projection so as to be barely distinguishable.

Larvae, pupae and imagos were easy to find through July and August, never in open water, and the imagos were not found away from water.

A single parasite bred from a puparium of this species, sent to Mr Ashmead for determination, proved to be new to science. At our request he has prepared the description of it, given on p. 588. Mr Ashmead says he believes that hitherto nothing has been known of the habits of wasps of the genus Atractodes.

## Tetanocera pictipes Loew

Plate 14, fig. 9–14

1859 Tetanocera pictipes Loew, Die nordamerikanischen arten der Gattungen Tetanocera und Sepedon Wiener. ent. monatschr. 3:292
1862 Tetanocera pictipes Loew, Monograph N. Am. Dipt. 1:111
1878 Tetanocera pictipes Osten-Sacken, Cat. Dipt. N. Am. p. 177.

I find no published account of the immature stages of any species in this large genus, save an antiquated one by Dufour for the European species T. ferruginea[1]. The figures are poor. There is an imago of this species, T. pictipes, in the Museum of comparative zoology, reared from the pupa by H. G. Hubbard at Milton Mass. Mar. 27, 1874, and another pupa is pinned beside it. I found larvae, pupae and imagos common at Saranac Inn, associated in all stages with Sepedon fuscipennis. The larvae and pupae are similar to the same stages in Sepedon, but more slender, and with good differential characters; they are apparently entirely similar in habits.

The imagos are found in the same bur reed beds, but they rest on the leaves habitually near the surface of the water, and so are little in evidence. Imagos of Sepedon, while not more common, were much more easily taken. In fact, I should probably not have found imagos of Tetanocera pictipes, had I not, after breeding one, gone out specially to look for them.

**Larva.** (Pl. 14, fig. 9, 10) Full grown. Length 10–12 mm; greatest thickness 1.8 mm.

Color transparent yellowish or greenish brown, lighter shades prevailing. Body cylindric, tapering anteriorly to a long point, and narrowed a very little just before the disk at the posterior end of the body. The relative lengths of the segments are about as given for the larva of Sepedon. The three rings of tubercles on each of the abdominal seg-

[1] 1849 Soc. ent. France. Ann. (2) 7:67, pl. 3.

ments are much the same, but the individual tubercles are in general a little more distinct in T. pictipes; the brush of hooked bristles on the dorsal locomotor tubercles is a little shorter (this is omitted altogether from Dufour's figure of the larva of T. ferruginea); there are four fairly distinct lateral tubercles each side in the median ring of the segment; the subterminal ring of lesser tubercles is less distinct than in S. fuscipennis, except on the ventral side where it is more distinct, and has the pair of little tubercles beside the midventral line fused more or less completely into one.

The respiratory float at the end of the body (pl. 36, fig. 4) is similar to that of S. fuscipennis, but is a little less copiously fringed, and the fringe is a little shorter, reaching but about two thirds of the distance to the margin of the disk. The fleshy processes and tubercles bordering the disk are very different. The ventral, submedian pair of processes are broad and blunt. The lateral processes have a broad obtuse base supporting a slender second joint. The tubercles forming the dorsal border of the disk, excepting the external one each side, are nearly obsolete. By the characters mentioned in this paragraph the larva of this species (possibly, of this genus) may readily be distinguished from Sepedon—at least, from Sepedon fuscipennis.

**Puparium.** (Pl. 14, fig. 11, 12) Length 6 mm; diameter 2 mm.

Color reddish brown, more reddish on the obsolescent larval tubercles, and on the upper side of the beak into which the body is contracted at the front end. There is no black arcuate mark at the base of the beak on the dorsal side.

Body more slender than in Sepedon, less convex below, less flattened above, though of much the same general appearance. The tail-like prominence at the posterior end bears at its apex the unaltered larval float, and at its sides the scarcely distinguishable remains of the processes and tubercles which surrounded the caudal disk of the larva. This "tail" is bent upward at an angle of about 45° with the axis of the body. By this lesser degree of angulation, as well as by the general slenderness of form, this species is readily distinguished from S. fuscipennis in the pupal stage.

## **Roederiodes juncta** Coquillet

Plate 15, fig. 5–8

The reader is referred to page 586 for the technical description of the imago of this species. It was found in a rapids in Little Clear creek just below the railroad embankment. Larvae and pupae were found first, the former crawling among the pupa cases of Simulium, the latter usually resting within an abandoned Simulium pupa case. After these had been bred, the imagos were found, clinging in companies to the under side of pieces of boards which rested just above the level of the water. They were not seen flying, except when disturbed, and then they took flight slowly and flew poorly. A piece of board might be lifted with a score of the flies sticking to it within an area of a few square inches, and most of them could be gathered into a cyanid bottle before

attempting to escape. The spot on the board where these groups occurred was always a wet one, and on it there was to be seen a mass of very minute white eggs in the midst of a matrix of thin, transparent gelatin. In these companies of adults, males and females were intermingled.

**Larva.** (Pl. 15, fig. 6) Length 5.7 mm; greatest diameter 1 mm.

Body cylindric, tapering anteriorly on the thoracic segments to the head, which is minute and more or less completely retracted within the prothorax. Segments increasing a little in thickness to the sixth abdominal, and in length to the seventh abdominal.

Color uniform whitish. Skin finely rugulose striate.

There are paired prominent ventral prolegs on the first eight abdominal segments; those on segments 1–7 similar, blunt, cylindric, equaling in length one third the diameter of the abdomen, bearing two terminal rows (of six to nine each) of thin, flat sharp, strongly curved exteriorly directed claws. Prolegs of the eighth segment longer, curved posteriorly, bearing a greater number of thin claws or hooks with apices directed anteriorly, the innermost much the largest.

There are two fine setae on the ventral side of the prothorax near its anterior end. The apex of the abdomen bears two pairs of setigerous processes, and below and at the sides of these a pair of low, bare, blunt prominences. The processes of the upper of the two above mentioned pairs, divaricate, wide apart, as long as the anterior prolegs, bearing each three setae longer than itself. The lower pair shorter, approximated on the apex of the abdomen, each with two shorter setae.

**Pupa.** Length 4.2 mm.

Free, cylindric, arcuate; clear yellow, with brownish spines and angles.

Face directed ventrally; two pairs of strong setae on the top of the head, with a corrugated surface between them; cases of the antennae simple, short, not exceeding half the length of the face. Mouth parts, wings and legs as usual, the hind legs under the wings. Prothorax at its anterior margin elevated in a pair of pyramidal triangular processes, directed above the hind angles of the head.

There are a few stiff setae on the thoracic dorsum; abdominal segments 1–8 bear each a median transverse whorl of stiff setae, alternating larger and smaller, and becoming much stouter dorsally toward the hind end of the abdomen and much fewer on the eighth segment; ninth segment very short, with a pair of apical lobes, each of which bears a strong, long, ventrally curved hook, as long as segments 8 and 9 together. On the inner side of this hook at its base is a minute, erect spinule.

## STRAY NOTES ON OTHER ORDERS

### ORTHOPTERA

No effort was made to collect these, but a few that were picked up incidentally were taken to Mr Scudder, who has kindly given me the following list of their names.

*Acrididae*

Tettix granulatus Kirby. This was not uncommon on the dry lichen mats on Blueberry island in Little Clear pond.

Tettigidea parvipennis Harris. In bogs on sphagnum.

Camnula pellucida Scudder

Dissosteira carolina Linnaeus

Spharagemon sp.? (nymph)

Podisma glacialis Scudder. On bushes in openings in the woods.

*Locustidae*

Scudderia pistillata Brunner

Xiphidium fasciatum DeGeer

### HEMIPTERA

I was struck with the absence of the larger aquatic Hemiptera, such as Belostoma, Zaitha, Nepa, etc., from all the waters in which I did any collecting about Saranac Inn. I was not looking for them; but, if they had ever got into my net, as they have done unfailingly in every other locality in which I have ever collected, they could not but have been seen. Of Ranatra I caught a few specimens in the vegetation about the shores of Bone pond. Of terrestrial Hemiptera there seemed to be no scarcity.

### MECOPTERA

Panorpa signifer Banks

Panorpa nebulosa Westw.

These were not uncommon in the damp woods along the road between the railroad and Little Green pond.

### COLEOPTERA

Though little attention was paid this order, considerable material was collected. But two species were reared, however: Galerucella nymphae and Donacia emarginata. The latter species was associated with D. subtilis Kunze and D. pusilla Say; and, because of unfamiliarity with the distinctive characters of Donacia larvae and pupae, I have been unable to determine as yet whether I have, among the numerous larvae collected, those of more species than the one that was reared. For the present, I content myself with giving a few biologic notes and figures. Plate 9, from photographs made from life, of Donacia emarginata Kirby on Sparganium in several stages will doubtless be welcome to entomologists. The material for these photographs was obtained while making the second quantitative study detailed in part 2, and farther oecological information is there recorded (see pages 404, 405).

A figure is also given of the singular bug-like Macronychus glabratus in plate 12 (fig. 9) a species commonly found associated

with fresh-water sponges on the under side of submerged logs. I found them mainly on logs which had shed their bark, but this may have been due to the greater ease of discovery on the smooth logs.

### HYMENOPTERA

A few representatives of this order, parasitic on aquatic insects, were found. Under the account of Chauliodes on page 547 there has been mentioned the minute egg parasite, Trichogramma minutum which was found a very abundant parasite of the eggs of one species of the above mentioned genus, destroying at least 70% of the eggs.

A new species of Atractodes was found parasitic on the swale fly, Sepedon fuscipennis, mentioned under the account of that species on page 580. A description of the parasite, furnished by Mr Ashmead, under the name Atractodes sepedontis Ashm. is given on page 588.

Four species of parasitic micro-hymenoptera were taken in the first qualitative study detailed above in part 2, page 403, all new to science. Mr Ashmead has at our request furnished descriptions (see pages 586–88).

A few sawflies, collected at random during the summer, were submitted to A. D. MacGillivray, who reports on them as follows.

### LIST AND TWO NEW SPECIES OF SAWFLIES

BY A. D. MACGILLIVRAY, CORNELL UNIVERSITY, ITHACA N. Y.

Trichiosoma angulatum Kirby
Tenthredo verticalis Say
Tenthredo rufipes Say
Pachyprotasis omega Norton
Pontania hyalina Norton
Dolerus bicolor Norton
Strongylogaster annulosus Norton

#### Pachynematus corticosus sp. nov.

♀ Black, with the following parts yellowish rufous, the clypeus, the tegulae, the apical margin of the pronotum, the apices of the coxae, the trochanters, the femora, the tibiae, except the posterior pair at apex, the front and middle tarsi, the middle pair slightly infuscated at apex, apical margin of abdominal tergites two to four, and the venter; the clypeus roundly emarginate, the lobes broad and evenly rounded, the head expanded back of the eyes, the vertex finely punctate, the lateral walls of the ocellar basin sharp and moderately well defined, the frontal crest well developed and not interrupted, the antennal fovea deep and elongate; the antennae elongate, tapering, the third segment slightly longer than the fourth; the sheath broad, its upper margin horizontal,

its lower margin strongly oblique and straight, and its apex broadly rounded; the veins and stigma black, the costa pale at base. Length, 7 mm. Habitat, Saranac Inn N. Y.

### Taxonus innominatus sp. nov.

♀ Black, with the following parts rufous: the labrum, the apical half of the mandibles, the femora, the tibia, the front tarsi, the apex of the second, and the entire third and fourth abdominal segments; the tegulae, the apices of the front and middle coxae, and trochanters lutescent; the clypeus deeply roundly emarginate; the third segment of the antennae longer than the fourth; wing veins blackish. Length, 8 mm. Habitat, Saranac Inn N. Y.

## ORIGINAL DESCRIPTIONS OF NEW DIPTERA

BY D. W. COQUILLETT, U. S. NATIONAL MUSEUM, WASHINGTON D. C.

ZABRACHIA, gen. nov. Stratiomyiidae

Closely related to Pachygaster, differing chiefly in the shortened, simple third vein. Head in profile only slightly higher than long; face and lower part of the front almost perpendicular; eyes nearly orbicular; antennae shorter than the head, the complex third joint transversely elliptic, the apical, slender style slightly longer than remainder of antennae; third vein of wings simple, terminating at about one third of the length of the second vein beyond the apex of the latter; four posterior cells, a part of each of them bordering on the discal cell. Type, the following species.

### Zabrachia polita sp. nov.

Black, polished, the antennae except the styles, also the tibiae, tarsi and apices of femora, yellow, knobs of halteres white, each marked with a black spot on basal half of the upper side; wings hyaline, stigma pale yellowish; length, 2.5 mm. Two females, collected Aug. 8, 1900, by Prof. James G. Needham.

**Type.** Cat. no. 5344, U. S. national museum

**Habitat.** Saranac Inn N. Y.

ROEDERIODES, gen. nov. Empididae

Closely related to Clinocera. Face bare, not separated from the cheeks by a groove; cheeks two thirds as broad as the eye hight; proboscis nearly as long as hight of head, rigid, the labella not developed; third joint of antennae oval, pointed at the apex, the apical style about as long as remainder of antennae; no acrostichal bristles, scutellum bearing bristly hairs in addition to the two marginal bristles; wings destitute of a brown stigmal spot, third vein forked, discal cell complete, sending two veins to the wing margin, of which the upper vein is forked,

hind cross vein very oblique, vein at apex of anal cell nearly perpendicular, sixth vein not prolonged beyond apex of anal cell; legs slender, destitute of bristles and of long hairs, pulvilli and empodia well developed. Type the following species.

### Roederiodes juncta, sp. nov.

Black, the coxae and femora yellow, tibiae and tarsi brown; head whitish pruinose, the front and upper part of the occiput grayish black; thorax opaque; mesonotum grayish black pruinose, an elongated spot in front of the scutellum and the pleura whitish pruinose; five pairs of dorsocentral bristles, scutellum, except its extreme base, gray pruinose, abdomen opaque, almost velvety; wings grayish hyaline, unmarked; length, 2.5 mm. Three female specimens, also one male without a head. Collected July 29, 1900, by Prof. James G. Needham. (Plate 15, figures 5–8)

**Type.** Cat. no. 5345, U. S. national museum

**Habitat.** Saranac Inn N. Y.

This genus is apparently nearest related to the European genus Roederia Mik, from which it differs in the absence of the stigmal spot and of the long hairs near the apices of the front femora; the venation also is different.

## DESCRIPTIONS OF FIVE NEW PARASITIC HYMENOPTERA

BY WILLIAM H. ASHMEAD, ASSISTANT CURATOR, U. S. NATIONAL MUSEUM

### Family 56 SCELIONIDAE

#### TELENOMUS Haliday

#### Telenomus longicornis sp. nov.

♂ Length 1.4 mm. Polished black; the antennae are much longer than the body, as in T. dolichocerus Ashm. the flagellum brown-black, hairy, the first joint of same being about the length of the third, the second joint very long, much longer than either the first or third, the fourth a little shorter than the third, the following joints very imperceptibly shortening. Wings hyaline, iridescent, the veins brown, the tegulae black. Legs black, the trochanters and tibial spurs pale yellowish, a dot on knees testaceous, the tarsi fuscous. Abdomen normal, the first segment longitudinally striate, the following smooth and polished.

**Type.** Cat. no. 5365, U. S. national museum

**Habitat.** Saranac Inn N. Y. One specimen taken in June 1900, by Prof. James G. Needham.

## Family 77 ALYSIIDAE

### BRACHYSTROPHA Förster

### Brachystropha quadriceps sp. nov.

♂ Length 1.8 mm. Polished black; mandibles rufous, palpi white; antennae black, 23 jointed, the scape beneath reddish, the extreme apex of the pedicel yellowish white; legs flavo-testaceous, the tibiae and tarsi darker, more of a reddish color, the tarsi fuscous. Wings hyaline, iridescent, the stigma and veins dark brown, the stigma subtriangular in shape, wider than the first abscissa of the radius and scarcely extending to half the length of the marginal cell.

The head is quadrate, with the temples broad, full, the face below the antennae smooth, impunctate, but with a delicate median ridge. The median fovea on the mesonotum posteriorly, so conspicuous in many forms, is very minute, nearly obsolete. The scutellum is bifoveate at base. The metathorax is rugulose, bare, but with a median carina. The mesopleural suture is distinct, crenate. The abdomen is clavate, the petiole being long and striate with prominent spiracles, the following segments all smooth, shining.

**Type.** Cat. no. 5366, U. S. national museum

**Habitat.** Saranac Inn; N. Y. One specimen in July by Prof. James G. Needham.

### RHIZARCHA Förster

### Rhizarcha astigma sp. nov.

♀ Length 2 mm. Polished black; mandibles rufous; palpi white; antennae black, 24 jointed, the scape and pedicel rufo-piceous, the latter narrowly yellow at apex; legs rufo-testaceous, the coxae and trochanters paler, more or less pale yellowish; wings hyaline, the veins brown.

The face below the antennae is feebly punctate and with a short median carina. The mesonotum posteriorly has a median fovea and a short grooved line just in front of the scutellum. The scutellum is bifoveate at base. The metathorax is rugulose but so densely clothed with a pale pubescence as to be obscured and the sculpture overlooked. The stigma in the front wings is not developed, being narrow and linear as in Aspilota. The mesopleural suture is distinct but smooth, not at all crenate. The abdomen is oblong oval, scarcely as long as the head and thorax united, the ovipositor not prominent, at the most subexserted, the first segment longitudinally striate, those beyond smooth and shining.

♂ Differs from the ♀ in having the antennae longer, 26 jointed, while the legs are slightly differently colored, the extreme apices of the middle and the hind tibiae and their tarsi being fuscous.

**Type.** Cat. no. 5367, U. S. national museum

**Habitat.** Saranac Inn N. Y. Taken in June and July by Prof. James G. Needham.

## Family 78 BRACONIDAE

### APHIDIUS Nees.

### Aphidius nigripes sp. nov.

♂ Length 1.5 mm. Entirely black except as follows: the extreme apex of the clypeus, the mandibles, the second joint of the trochanters and the knees are honey-yellow, the tibiae and tarsi dark brown or fuscous, almost black. The antennae are 19 jointed, longer than the body, the joints of the flagellum being not quite thrice as long as thick. Wings hyaline; tegulae and veins brown, the stigma *within*, the recurrent nervure, the transverse cubitus and the second abscissa of the radius being pallid or subhyaline.

**Type.** Cat. no. 5368, U. S. national museum

**Habitat.** Saranac Inn N. Y. Taken in June and July by Prof. James G. Needham.

This species in a table of our species, prepared for my *Monograph of the North American Braconidae*, falls next to A. obscuripes, but is distinguished by the color of the legs and differences in antennal characters.

## New stilpnine parasitic on dipterous puparia

### Atractodes sepedontis sp. nov.

♀ Length 5 mm. Black, with the second and third abdominal segments, the mandibles, and the legs, except the hind tarsi rufous; hind tarsi dark fuscous or black. Antennae 21 jointed, black, the third joint the longest, a little longer than the second, the following gradually and almost imperceptibly shortening. Head and thorax polished, the parapsedal furrows well defined anteriorly, gradually becoming obsolete posteriorly before attaining the base of the scutellum. Mesosternum and metathorax rugulose opaque, the latter sloping from the base to apex, with the basal lateral and pleural areas alone well defined. Wings hyaline, the stigma and veins dark brown, the tegulae, the median and submedian veins in the front wings toward the base and the subcostal vein in the hind wings

yellowish; areolet open, the submedian cell a little longer than the median. Abdominal petiole about wice as long as the hind coxae, bifurrowed and subcoriaceous above.

**Type.** Cat. no. 5316, U. S. national museum

**Habitat.** Saranac Inn N. Y.

Host. Diptera: Sepedon fuscipennis Loew. Bred Aug. 24, 1900, from a puparium of Sepedon fuscipennis Loew, by Prof. James G. Needham.

This species comes very close to the European Atractodes gravidus Haliday; but is readily distinguished by a slight difference in color and by decided differences in antennal and metathoracic characters.

## EXPLANATION OF PLATES

### PLATE 1

Outlet of Little Clear pond; view, looking northward from the railroad. Photo by J. G. Needham

### PLATE 2

Little Clear pond; view from the outlet, looking toward Green hill: St Regis mountain in the distance. Photo by J. G. Needham

### PLATE 3

Little Clear creek on the grounds of the Adirondack hatchery; looking down stream from the railroad. Photo by C. Betten

### PLATE 4

Little Clear creek just below the hatchery. Photo by R. C. Spears

### PLATE 5

Little Clear creek at the edge of the woods below the hatchery; cages, nets and trap lantern. From the bare strip partly occupied by a single screen cage in the foreground the first quantitative study detailed in part 2 was made. Photo by J. G. Needham

### PLATE 6

Little Clear creek on the hatchery grounds, looking toward the railroad. From the boarded bank of the pool in the foreground the dragonfly exuviae were collected for the count recorded in part 2. Photo by J. G. Needham

### PLATE 7

View across Little Bog pond, from the "carry". Photo by J. G. Needham

### PLATE 8

Shore of Little Bog pond. Photo by C. Betten

### PLATE 9

Bur reed (Sparganium) with long-horned leaf beetles (Donacia emarginata Kirby). *a* summit of the plant, with beetle on the leaf (greatly reduced); *b* roots as withdrawn from the water, with larval and pupal cases of the beetle attached (slightly reduced). Photos by J. G. Needham

### PLATE 10

FIG. **Leucorhinia glacialis** Hagen

1 Two nymphs on the bottom of the pond
2 The empty nymph skin, left clinging to a branch after transformation
3 The female imago
4, 5 Dorsal and lateral views of the male imago

## PLATE 11

### **Ephemera varia** Etn., and **Siphlurus alternatus** Say

FIG.
1 Lateral view of the nymph of E. varia
2 Dorsal view of the nymph of E. varia
3 Lateral view of the male imago of E. varia
4 Dorsal view of the male imago of E. varia
5 Lateral view of the nymph of S. alternatus
6 Dorsal view of the nymph of S. alternatus
7 Lateral view of the male imago of S. alternatus

## PLATE 12

### **Climacia dictyona** Needham, nov. sp., and **Sisyra umbrata** Needham, nov. sp.

FIG.
1 Imago of C. dictyona, lateral view, x 4
2 Imago of C. dictyona, dorsal view, x 3
3 Larva of C. dictyona, dorsal view, x 6
4 Pupal cases of C. dictyona, in situ, natural size
5 One of the same, enlarged, showing the hexagonal meshes of the outer covering
6 Imago of S. umbrata, lateral view, x 4
7 Imago of S. umbrata, dorsal view, x 3
8 Two newly formed pupae of S. umbrata, lateral and ventral views, x 6
9 Macronychus glabratus Say (Coleoptera: Parnidae); an associate of the sponge fly larvae, on submerged timbers
10 Fresh-water sponges (Spongilla ?fragilis Leidy) in situ, with the sponge fly larvae crawling about over them
11 Two pupal cases of S. umbrata, showing the closely woven outer covering, natural size

## PLATE 13

### **Molanna cinerea** Hagen and **Polycentropus lucidus** Hagen

FIG.
1 Dorsal view of larva of Molanna cinerea, x4
2 Lateral view of larva of M. cinerea, x5
3 Lateral view of the pupa of M. cinerea, x4½
4 Dorsal view of imago of M. cinerea, x4
5 The accustomed resting position of the imago of M. cinerea
6 Ventral view of the flat larval case of M. cinerea, x2
7 Lateral view of larva of Polycentropus lucidus, showing the very long anal prolegs, and the absence of gill filaments, x5
8 Lateral view of pupa of P. lucidus, x6
9 Dorsal view of imago of P. lucidus, x3½
10 Larval case of P. lucidus; tube composed of sand and silk; the enlargement near the end is two layered, and contains the pupa.
11 Eggs laid by P. lucidus female on a stick protruding from the water in a breeding cage

## PLATE 14

### Sepedon fuscipennis Loew and Tetanocera pictipes Loew

FIG.

1 Larva of S. fuscipennis, dorsal view, x 5
2 Larva of S. fuscipennis, lateral view, x 6
3 Puparium of S. fuscipennis, dorsal view, x 5
4 Puparium of S. fuscipennis, lateral view, x 5
5 Open puparium of S. fuscipennis, x 5
6 A seed floating which the puparium simulates, x 5
7 Imago of S. fuscipennis, dorsal view, x 5
8 Imago of S. fuscipennis, lateral view, x 5
9 Larva of T. pictipes, dorsal view, x 6
10 Larva of T. pictipes, lateral view, x 6
11 Puparium of T. pictipes, lateral view, x 6
12 Puparium of T. pictipes, dorsal view, x 5
13 Imago of T. pictipes, dorsal view, x 5
14 Imago of T. pictipes, lateral view, x 5

## PLATE 15

### Simulium Society

Simulium venustum Say, Hydropsyche sp.?, Heptagenia pulchella Walsh, Baetis pygmaea Hagen, Leuctra tenella Provancher and Roederiodes juncta Coquillett.

FIG.

1 Two imagos of Hydropsyche sp.?, at rest, natural size
2 Imago of Hydropsyche sp.?, lateral view, x 6
3 Larva of Hydropsche sp.?, lateral view, x 3½
4 Pupal case of Hydropsyche sp.?, x 2
5 Imago of Roederiodes juncta, lateral view, x 10
6 Larva of Roederiodes juncta, lateral view, x 5
7 Pupa of Roederiodes juncta, lateral view, x 5
8 Pupa of Roederiodes juncta in an habitual position in the abandoned pupal case of Simulium venustum
9 Egg masses of S. venustum, and two females ovipositing
10 Pupae, empty pupa skins, and pupal cases of S. venustum
11 Larva of S. venustum, x 5
12 Male imago of Leuctra tenella, dorsal view, x 4
13 Imago of Baetis pygmaea, lateral view, x 5
14 Imago of Baetis pygmaea, dorsal view, x 5
15 Imago of Heptagenia pulchella, x 2
16 Nymph of Heptagenia pulchella, natural size
17 Pupal cases of Hydropsyche sp.?, in situ. natural size
18 Pupae of Simulium venustum, in situ
19, 20 Larvae of S. venustum in situ

## PLATE 16

### **Hexagenia variabilis** Eaton

FIG.

1 Female imago, natural size. Photo from life by J. G. Needham

2 Dorsal view of the head of the nymph

3, [a]Fore and [b]hind feet of the nymph; [f]femur; [t]tibia

## PLATE 17

### Dragonflies

FIG.

1 Aeschna constricta Say

2 Gomphus scudderi Selys

Natural size: photos from life by J. G. Needham

## PLATE 18

Dragonfly nymphs: photos by J. G. Needham

FIG.

1 Dromogomphus spinosus Selys

2 Gomphus scudderi Selys

3 G. brevis Selys

4 G. spicatus Selys

5 Ophiogomphus aspersus Morse

6 Lanthus parvulus Selys

7 Hagenius brevistylus Selys

8 Didymops transversa Say

Fig. 1 to 7 are from cast skins.

## PLATE 19

Eggs of nine genera of dragonflies (Odonata-Anisoptera)

FIG.

1 Egg of Anax junius Dru: the line k-k indicates the depth of its insertion into cat-tail (Typha) stems.

2 Egg of Hagenius brevistylus Selys

3 Egg of Gomphus descriptus Banks var. borealis Ndm.

4 Egg of Cordulia Shurtleffi Scudd.

5 Egg of Plathemis lydia

6 Egg of Leucorhinia glacialis Hagen

7 Egg of Celithemis eponina Dru.

8 Egg of Perithemis domitia Dru.

9 Egg of Tramea lacerata Hagen

Gelatinous envelops (g) are indicated for all the figures except 1 and 8: all are magnified about 50 diameters.

## PLATE 20

### Gomphinae

FIG.

1–4 Occiput of the female of Ophiogomphus carolus Ndm., seen from the front, showing variations in occipital spines

5 Genital hamules of O. johannus Ndm., from the left side, inverted

FIG.

6 Genital hamules of O. carolus Ndm.

7 Inferior abdominal appendage of O. carolus Ndm., seen from below

8 Head of nymph of Lanthus parvulus Selys, seen from above and in front

9 Mentum of labium of L. parvulus from above

10 End of abdomen of L. parvulus

11 End of abdomen of Gomphus fraternus Say, nymph

12 Part of labium of G. fraternus Say, nymph

13 End of abdomen of Gomphus pallidus Selys, nymph

14 Part of labium of Gomphus pallidus Selys, nymph

15 End of abdomen of Gomphus spiniceps Walsh, nymph

16 Part of labium of Gomphus spiniceps Walsh, nymph

From the *Canadian entomologist*, 1897, v. 29, pl. 7, "Preliminary studies of North American Gomphinae," by James G. Needham.

PLATE 21

## Cordulinae

FIG.

1 Somatochlora elongata Selys. Photo from life by J. G. Needham

2 Cast nymph skin of Epicordulia princeps Hagen: drawn by Mrs Needham

PLATE 22

## Cordulinae

FIG.

1 Epicordulia princeps Hagen, ♀: drawing by Mrs Needham

2 Tetragoneuria spinosa Selys, ♀ showing peculiar wing markings. Photo by H. N. Howland.

PLATE 23

## Libellulinae

FIG.

1 Libellula semifasciata Burm.

2 L. pulchella Dru.

PLATE 24

## Libellulinae

FIG.

1 Plathemis lydia Dru.

2 Celithemis eponina Dru.

3 Perithemis domitia Dru. ♂

4 P. domitia Dru. ♀

PLATE 25

## Nymphs of Sympetrum

FIG.

1 Sympetrum illotum Hagen

2 Sympetrum semicinctum Say

## PLATE 26

### Neuroptera

FIG.

1 Chauliodes serricornis Say, newly transformed. The cast off pupal skin is seen hanging out of burrow in rotten wood. Photo from life by J. G. Needham

2 Polystoechotes punctatus Say. Photo by J. G. Needham

## PLATE 27

### Chauliodes serricornis Say

*a* A pair *in copulo* beneath a leaf of the flowering fern (Osmunda regalis L.; a large number of eggs already present.

*b* Same pair, enlarged

*c* Female of the same pair, ovipositing later

Photos from life by J. G. Needham

## PLATE 28

Horned Corydalis, Corydalis cornuta Linn.: [a]the larva; [b]the pupa [c]the male imago; [d]head and thorax of the female (after Riley)

## PLATE 29

### Sialis infumata Walk.

FIG.

1 Wing of the imago

2 Lateral view of the pupa

3 Dorsal view of the larva

Drawings by Miss Anthony

## PLATE 30

### Caddis flies (Trichoptera)

FIG.

1 Phryganea cinerea Walker

2 Goniotaulius dispectus Walker

3 Halesus indistinctus Hagen

## PLATE 31

### Caddis flies (Trichoptera)

FIG.

1 Halesus hostis Hagen

2 H. sp.?

## PLATE 32

### Caddis flies (Trichoptera)

FIG.

1 Larva of Halesus sp.? no. 3, dorsal view

2 Larva of Halesus sp.? no. 2, dorsal view

3 Larva of Halesus sp.? no. 1, dorsal view

4 Pupa of Halesus sp.? no. 3, lateral view

5 Pupa of Halesus sp.? no. 2, lateral view

6 Pupa of Halesus sp.? no. 1, lateral view

PLATE 33

## Caddis fly cases and eggs

Fig.

1 Larval case of Halesus sp.? no. 3

2 Larval case of Halesus sp.? no. 2

3 Larval case of Halesus sp.? no. 1

4 Egg ring of an unknown caddis fly. Photo by C. Betten from life

PLATE 34

## Caddis flies (Trichoptera)

Fig.

1 Leptocerus resurgens Walker

2 Triaenodes ignita Walker

3 Hydropsyche scalaris Hagen

PLATE 35

## Diptera

Fig.

1 Stratiomyia badius Walker; drawing by Miss Anthony

2 Tipula abdominalis Say, photo by H. N. Howland

PLATE 36

## Larvae of Diptera

Fig.

1 Dorsal view of larva of Tipula abdominalis Say

2 End of abdomen of same, more enlarged

3 *a* Dorsal prolegs of one segment of larva of Sepedon fuscipennis Loew (developed for crawling beneath the surface film)

*b* End of abdomen of larva of Sepedon fuscipennis Loew

4 End of abdomen of larva of Tetanocera pictipes Loew

Photo by J. G. Needham

Outlet of Little Clear pond—view from the railroad

Photo by J. G. Needham

Little Clear pond—view from the outlet toward Green hill. St Regis mountain in the distance

Photo by C. Betten

Little Clear creek on the grounds of the Adirondack hatchery, looking downstream from the railroad

Photo by R. C. Spears

Little Clear creek below the hatchery

Photo by J. G. Needham

Little Clear creek at edge of woods below the hatchery. Cages, nets and trap lantern

Photo by J. G. Needham

Little Clear creek on the hatchery grounds looking toward the railroad

Photo by J. G. Needham

General view of Little Bog pond

Plate 8

Photo by C. Betten

Shore of Little Bog pond

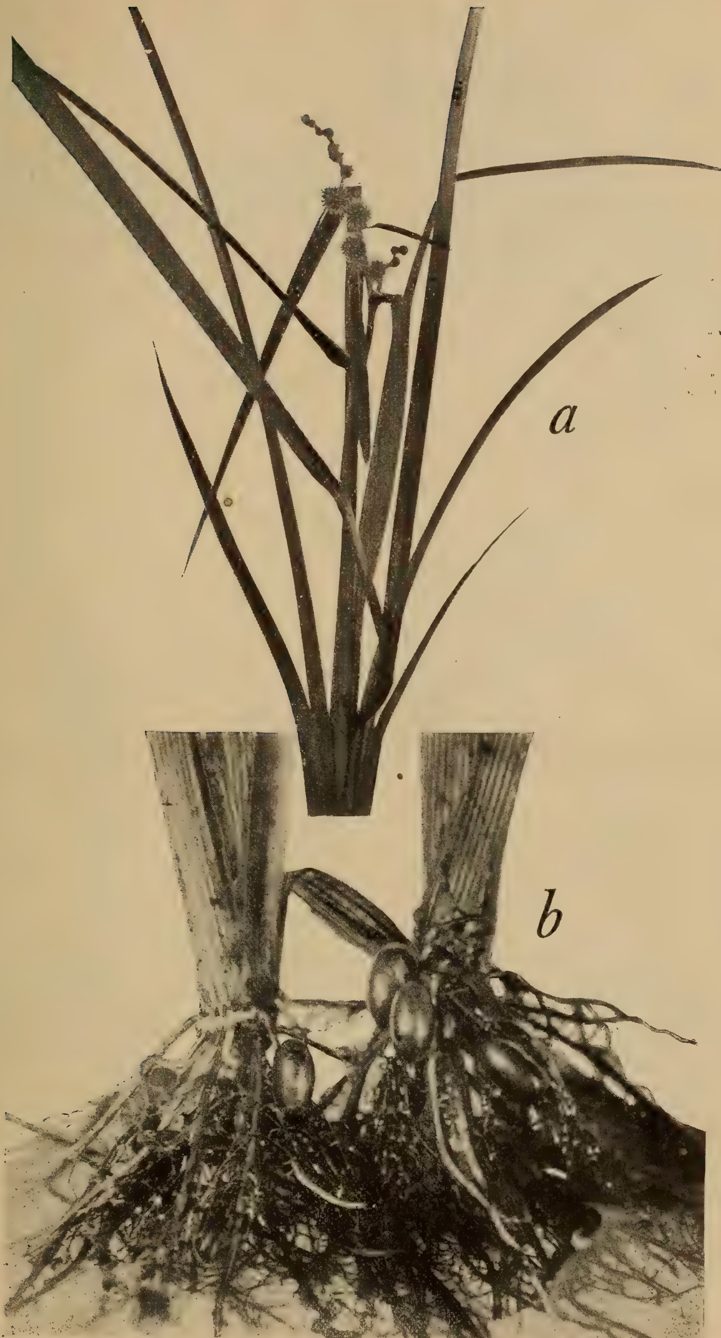



Photo from life, by J. G. Needham

Sparganium with long-horned leaf-beetles (Donacia): larval and pupal cases on the roots


L. H. Joutel, 1900

James B. Lyon, State Printer

Leucorhinia glacialis


L. H. Joutel, 1900

James B. Lyon, State Printer

Mayflies


L. H. Joutel, 1900

James B. Lyon, State Printer

Spongilla flies


L. H. Joutel, 1900

James B. Lyon, State Printer

Caddis flies


L. H. Joutel, 1900

James B. Lyon, State Printer

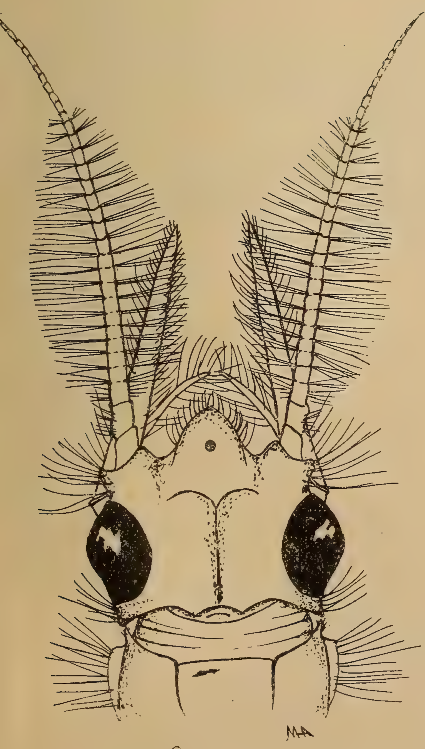
Sepedon and Tetanocera


L. H. Joutel, 1900

James B. Lyon, State Printer

Simulium society

1

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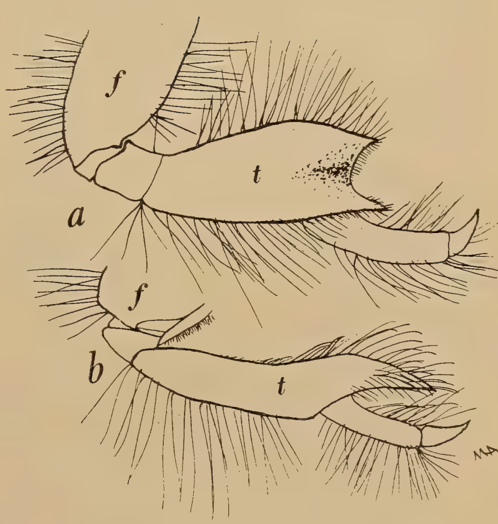



3

1

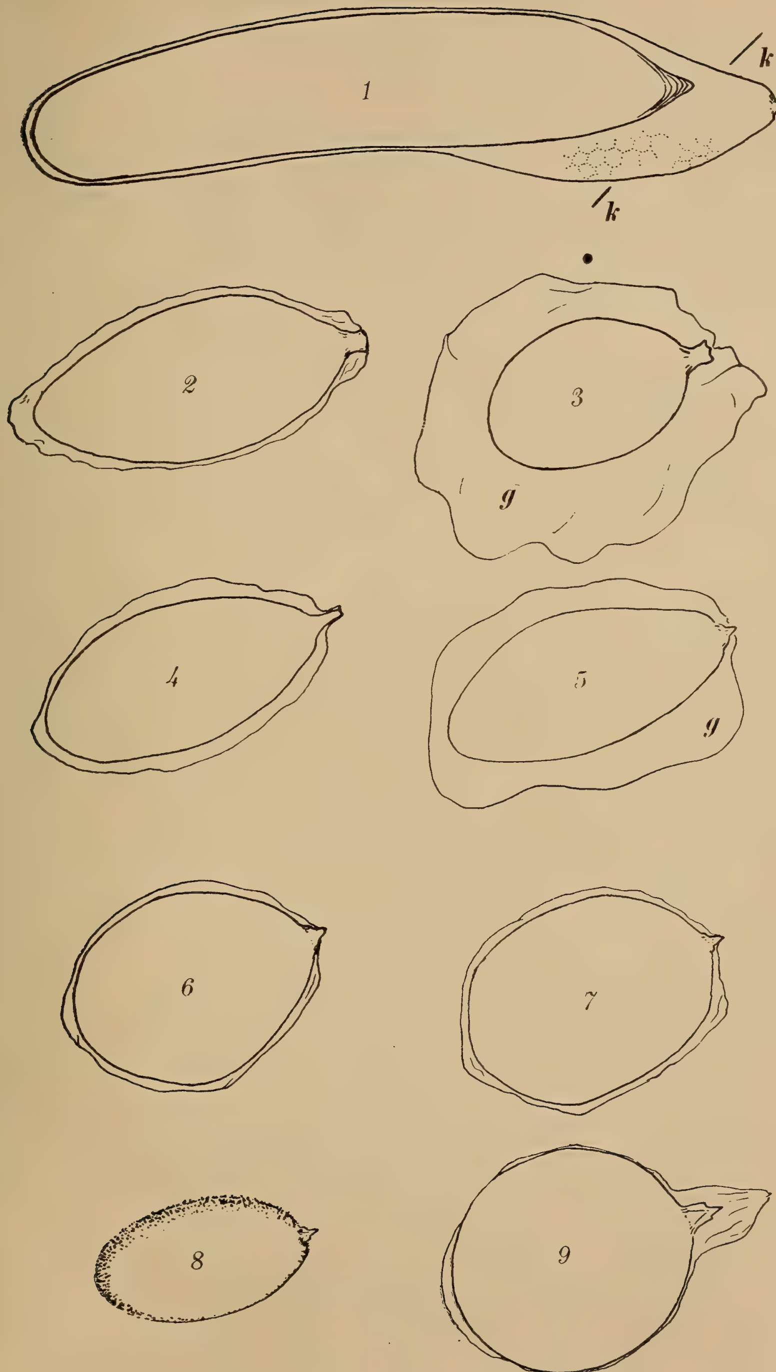
2

1 Aeschna constricta Say
2 Gomphus scudderi Selys

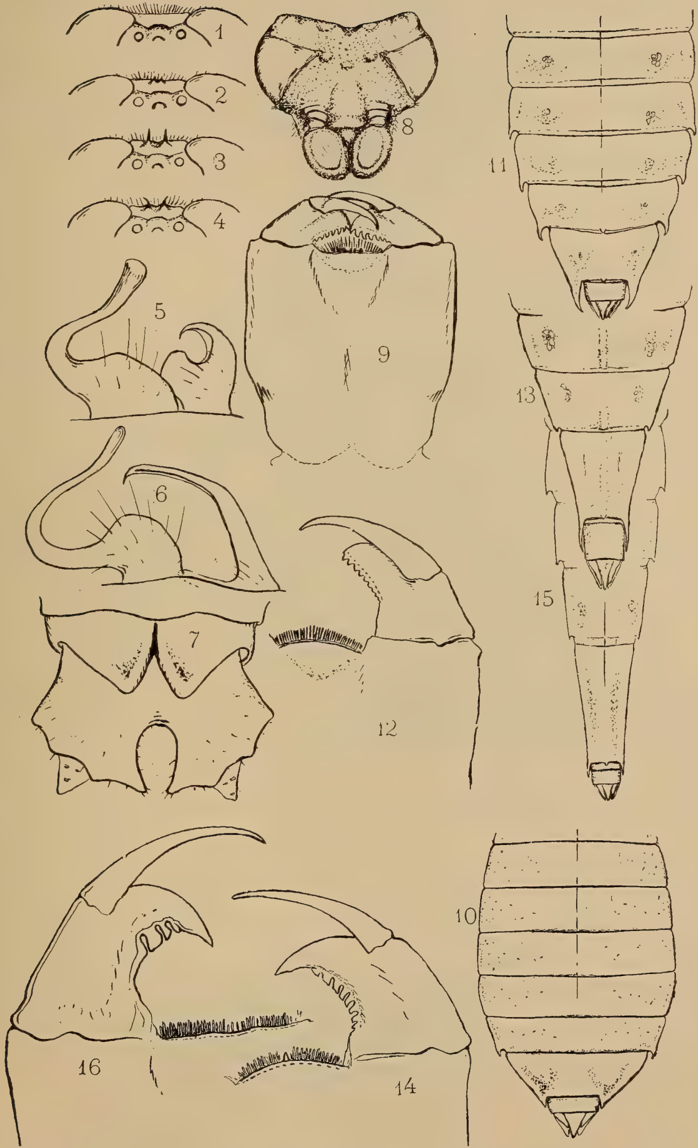

8

Photos by J. G. Needham

Dragon-fly nymphs




Eggs of nine genera of dragon-flies




From *Canadian entomologist* v. 29, pl. 7 (1897)

Structural characters of Gomphinae

Photo from life by J. G. Needham

1

Drawing by Mrs J. G. Needham

2

1 Somatochlora elongata Selys

2 Epicordulia princeps Hagen

CORDULINAE

Plate 22

Drawing by Mrs J. G. Needham

1

Photo by H. N. Howland

2

1 Epicordulia princeps Hagen ♀

2 Tetragoneuria spinosa Selys ♀ nat. size

CORDULINAE

1

2

1 Libellula semifasciata Burm.

2 Libellula pulchella Dru.

LIBELLULINAE

Plate 24

1

2

3

4

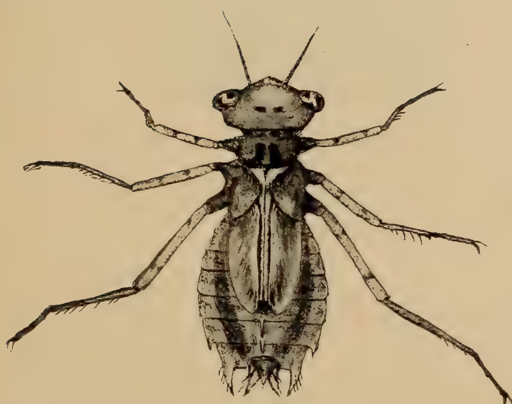
1 Plathemis lydia Drury

2 Celithemis eponina Drury

3, 4 Perithemis domitia Drury, ♂ and ♀

LIBELLULINAE

1



2

1 S. illotum Hagen

2 S. semicinctum Say

NYMPHS OF SYMPETRUM

Plate 26

Photo from life by J. G. Needham, nat. size

1

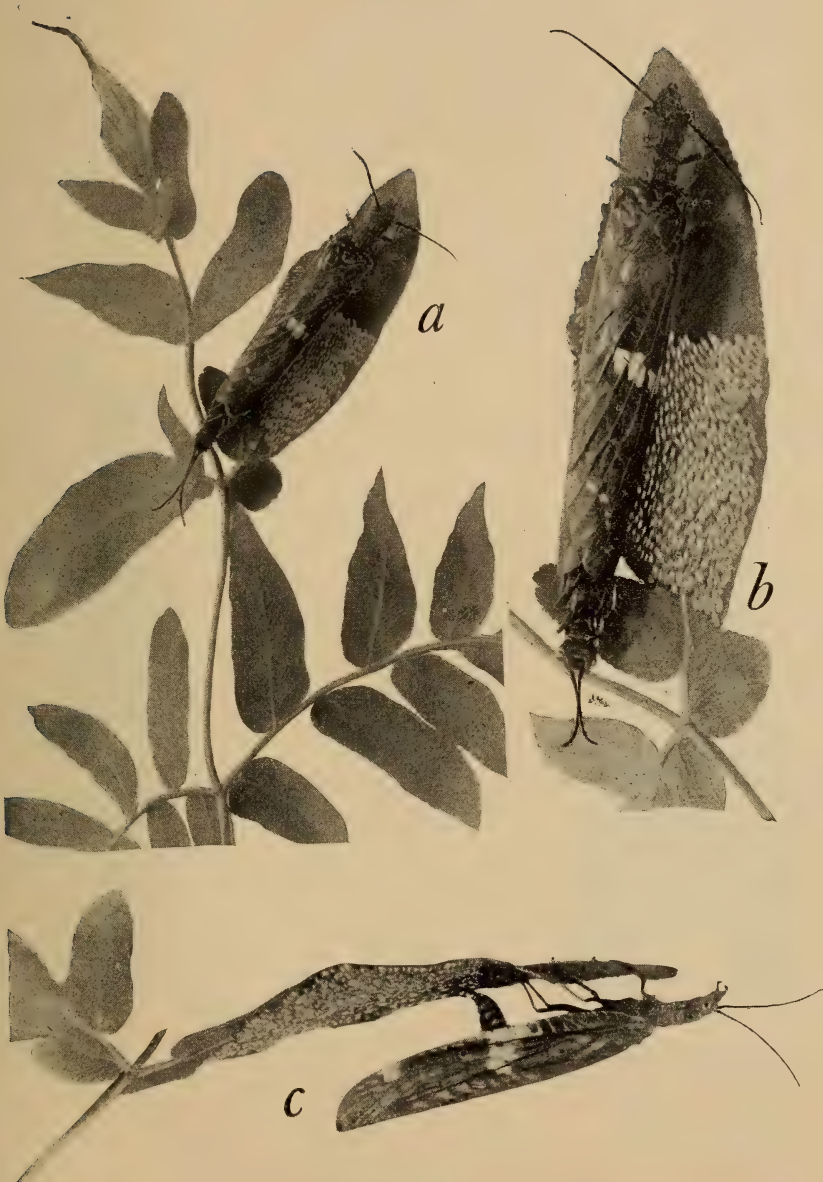
Photo of living but partly anesthetized specimen by J. G. Needham

2

1 Chauliodes serricornis Say, newly transformed

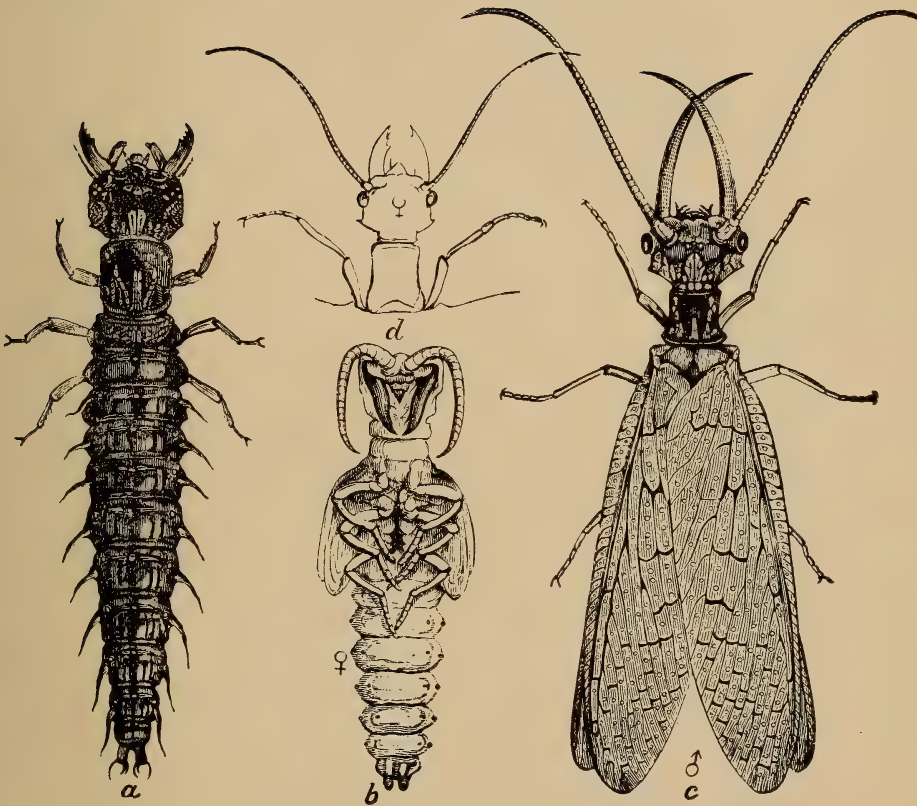
2 Polystoechotes punctatus Say

NEUROPTERA



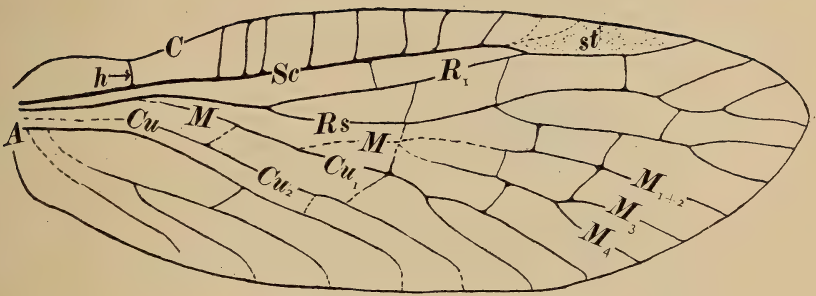

Photos from life by J. G. Needham

Chauliodes serricornis Say



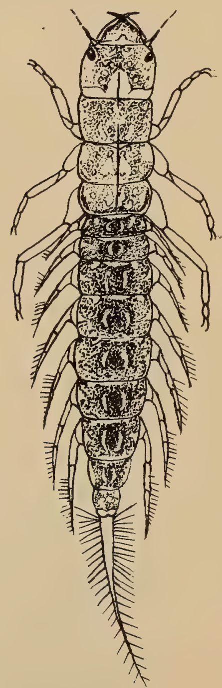

Horned Corydalis, Corydalis cornuta (After Riley)

Plate 29




1

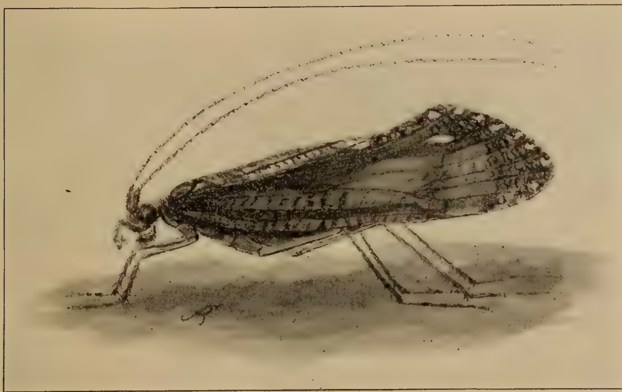
2



3

Drawings by Miss Anthony

Sialis infumata Walk



1

2

3

Drawings by Mrs J. H. Comstock

1 Phryganea cinerea Walk.
2 Goniotaulius dispectus Walk.
3 Halesus indistinctus Hagen

CADDIS FLIES

1

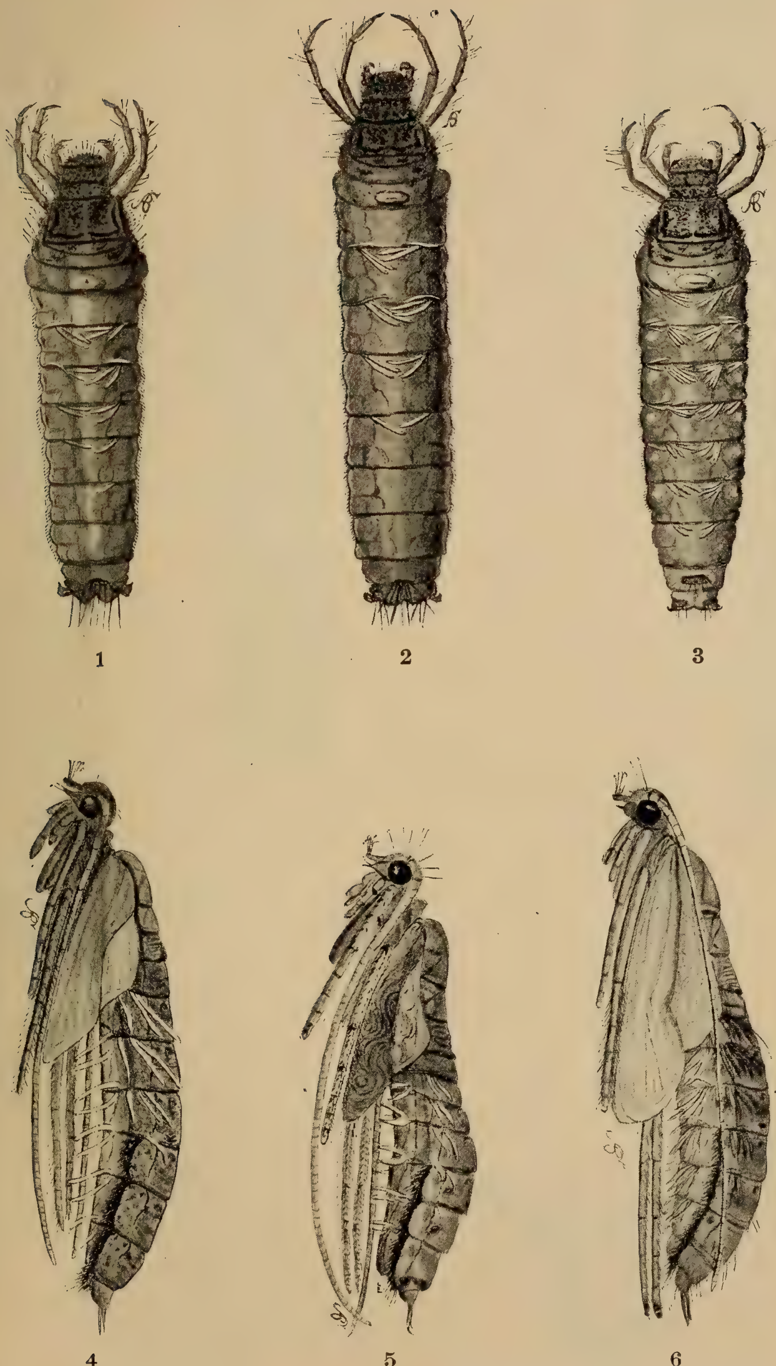
2

Drawings by Mrs J. H. Comstock

1 Halesus hostis Hagen
2 Halesus species

CADDIS FLIES

Plate 32




Drawings by Mrs J. H. Comstock

Caddis flies larvae and pupae

1

2

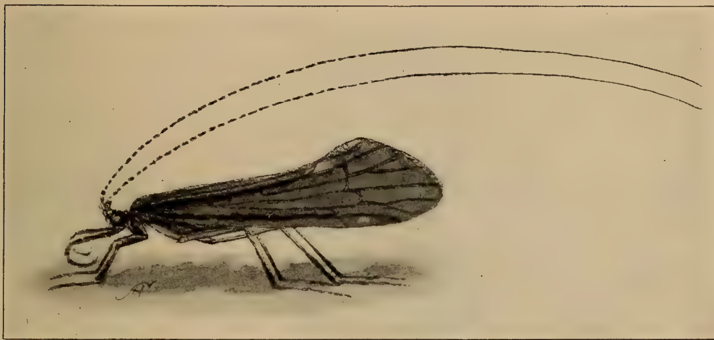
3

Photo from life by C. Betten

4

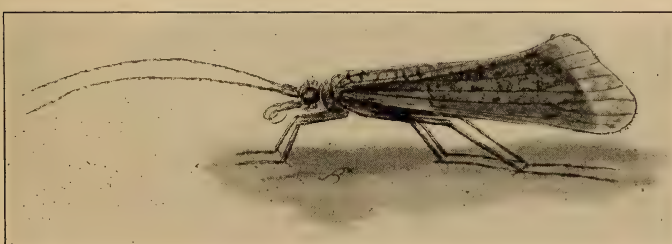
Drawings (fig. 1-3) by Mrs J. H. Comstock

Caddis fly cases and eggs



1

2



3

Drawings by Mrs J. H. Comstock

1 Leptocerus resurgens Walk.

2 Triaenodes ignita Walk.

3 Hydropsyche scalaris Hagen

CADDIS FLIES

Drawing by Miss Anthony

1

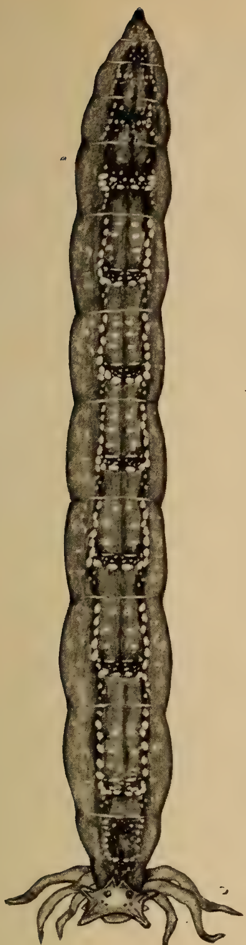
Photo by H. N. Howland

2

1 Stratiomyia badius Walk.

2 Tipula abdominalis Say ♀ nat. size

DIPTERA



1


3

4

2

Fig. 3, 4. Drawings by Miss Anthony

1, 2 Tipula abdominalis Say
3 Sepedon fuscipennis Loew
4 Tetanocera pictipes Loew
DIPTERA

## TEXT ILLUSTRATIONS

# INDEX

The superior figures tell the exact place on the page in ninths; e. g. $458^{3}$ means page 458, beginning in the third ninth of the page, i. e. about one third of the way down.

(*Pages 613-614 were bulletin cover pages*)

University of the State of New York

# New York State Museum

FREDERICK J. H. MERRILL Director

Bulletin 48 December 1901

# PLEISTOCENE GEOLOGY

OF PORTIONS OF

# NASSAU COUNTY AND BOROUGH OF QUEENS

BY

JAY BACKUS WOODWORTH B.S.

University of the State of New York

# New York State Museum

Frederick J. H. Merrill *Director*

Bulletin 48 December 1901

## PLEISTOCENE GEOLOGY

OF PORTIONS OF

## NASSAU COUNTY AND BOROUGH OF QUEENS

### PREFACE

The following report by Prof. Woodworth on the results of field work in western Long Island is in continuation of an investigation of the quaternary formations of Long Island and the Quaternary history of the Hudson river valley begun in 1883 by the present state geologist.

The great development of the branch of Quaternary investigation makes it now possible to seek positive proof where formerly only broad inferences could be drawn.

Prof. Woodworth's work will include the Hudson and Champlain valleys and the drainage basins tributary to them and his results may be expected to contribute an important chapter to American Quaternary history.

Frederick J. H. Merrill
*State geologist*

## INTRODUCTION

The term Pleistocene is used here as the equivalent of Quaternary, a term which has heretofore been employed in the museum reports for the period of great ice sheets.

The Oyster Bay and Hempstead quadrangles together include a belt about 13 miles wide extending north and south across Long Island. The area thus mapped comprises, aside from a triangular area on the mainland about Mamaroneck not dealt with in this report, the major portion of the towns of Oyster Bay, North Hempstead, and Hempstead, the coast of Long Island sound from Manhasset bay on the west to Oyster Bay harbor on the east, and the Atlantic shore from the eastern part of Far Rockaway beach, eastward to Short beach.

The matters considered in this report are 1) the topography, 2) glacial deposits, 3) Pleistocene history, including data gathered from the area on the west, 4) the post-glacial changes and processes now in action.

### TOPOGRAPHY

As the traveler from Greenport or Sag Harbor approaches the western end of Long Island, there are more or less continuously before him two low ridges, one skirting the north shore of the island, the other less elevated and continuous and at a variable distance inland from the south shore, the two being separated first by the deep embayments of the pronglike eastern end of the island, and then by a broad, sandy plain, narrowing westward to the eastern limits of the area with which this report is concerned. At this point, near Syosset, the north and south ridges rudely coalesce. The northern ridge takes a south southwesterly course, lies more remote from the shore of the sound, and traverses the area so as to inclose the southern ends of the V-shaped harbors of Manhasset and Great Neck bays.

What appears to be a continuation of the southern ridge is traceable as a series of low mounds at Locust Grove, Jericho, thence south of Old Westbury, at Albertson station, Searington, and so westward to an abrupt termination at the base of the higher, more massive northern ridge just east of Lake Surprise. Between these mounds

and the northern ridge rude plains of coarse gravels rise gently toward the southern face of the latter. Between the mounds themselves, these plains merge southward into a broad, slightly creased plain, which sinks to the level of the marshes and the sea on the south coast.

The main ridge rises very frequently to a hight of 300 feet above sealevel, and from 100 to 150 feet above the low ground at its base. Where most distinct in its topographic features, its base is but little more than a mile wide. Between Syosset on the south and East Norwich and Brookville on the north side, this ridge is relatively low and narrow. Between Jericho and Wheatley three or four well marked spurs extend for one or two miles to the southward, impinging on the line of mounds representing the continuation of the southern ridge above described. West of this broad development, the ridge becomes more massive and elevated, attaining its highest point in Harbor hill, 391 feet. West of Roslyn, it gradually falls off in elevation, and from Lake Surprise westward becomes a low, flat ridge with a steep southerly front and with a gentle slope northward. The broad crest, seldom over 200 feet above the sea, is cast into mounds and hollows, or knobs and basins, some of the latter containing small tarns or lily ponds, a feature less common in the eastern extension of the ridge.

From the northern base of the ridge there extends a series of plains or terraces, frequently at an elevation of about 200 feet near the ridge, separated by the wedge-shaped harbors of the north shore. These surfaces form the headlands or "necks," between the bays, with elevations of from 100 feet to nearly 200 feet. The surface is deeply indented by valleys mouthing on the broader indentations of the coast line; and in the vicinity of Oyster Bay harbor the land is reduced to a few islands, now tied to the main island by marine beaches.

Between these rude plains on the north and the broad plain on the south the deeper reentrants of the northern coast are continued by narrow depressions across the main ridge. One of these troughs occurs south of Manhasset, another at Roslyn, and similar passes traverse the ridge at the eastern base of the Harbor hill mass, on the road from Brookville to Locust Grove, and eastward along the

line of the highways connecting Syosset with towns on the northern side of the ridge.

The northern plains varying from 190 to 220 feet in elevation are well developed about East Norwich. Their surface is roughened and is usually more uneven than the 20 foot contours of the accompanying map can be made to indicate. These upper plains frequently overlook like a terrace lower levels of much more uneven surface near the 100 foot level, as between Manhasset hill and Flower hill, between Greenville station and Glenwood landing, and on the borders of Mill Neck creek. The terraciform slopes are like the sides of those valleys which dissect the rude plains, usually irregular, roughly lobate or cuspate, and sloping without sharp demarcation into the lower grounds which they overlook. The northern margin of these dissected plains often reveals them as mere narrow ridges with rounded summits, and with small bays or marshes on either side, as at Mill Neck.

The broad southern plain needs little more description beyond that already given than to note a low ridge, about 20 feet in elevation and from a mile to 2 miles wide, springing out from the plain near Lynbrook, and extending southwestward parallel to the main ridge farther north, till it is cut off by the sea at Far Rockaway. Associated with this ridge is the semicircular depression on the west known as Jamaica bay, largely marsh-filled, and an extension of this feature in the region of Broad channel. Along both north and south shores are bars and beaches, with cliffs, produced by the recent work of the sea.

A summarized view of the island in this region would be fairly represented in a cross-section, such as that shown in fig. 1, in which the northern, rude, terraced plains rising rather abruptly above the sound are succeeded on the south by the main ridge and the outlying knobs, from which there stretches a broad plain sloping southward to the sea or confronted near Far Rockaway by a low ridge, beyond which in turn lie the south beaches.


Fig. 1 Diagrammatic cross-section of Long Island near the boundary line of Queens and Nassau counties

The main topographic features thus set forth are traceable eastward for 200 miles, one or more elements appearing either on the islands off the south coast of New England or on the adjacent mainland, the essential elements of the topography being two ridges each one of which rises rather abruptly above a plain sloping southward from it toward the sea. If the plain is absent, the sea covers the space where we should expect it to occur. Westward, the main ridge here described abuts on lower New York bay at the Narrows, reappearing on Staten Island and continuing to be recognizable far inland over the continent as a topographic feature, often imposed on the rocky profile of valleys and high ridges alike.

## GEOLOGY

The topographic features above described have long been known to constitute a group of drift materials laid down along the margin of an ice sheet or a successive series of such glaciers in the Quaternary or, as it is now usually denominated, the Pleistocene period, a time defined as beginning in this hemisphere with the first of these ice invasions on the coast plain and closing with the final disappearance of the ice from eastern America. The time since this disappearance of the ice, variously estimated at from 7000 to 10,000 years, is frequently denominated the post-glacial epoch. With the deposits made during this Pleistocene period, the present report has mainly to do.

### Pre-Pleistocene formations

The basement on which these Pleistocene drift materials repose in this part of Long Island has but a small exposure above sealevel, and that is mainly limited to the northern coast north of the main ridge, or moraine. These older materials are clays and sands, evidently an eastward extension of the nearly horizontal clays and sands largely of Cretaceous and late Jurassic age which constitute a large part of the coastal plain from New Jersey southward. Little is known of the attitude of these beds in this region, prior to the earliest ice invasion, farther than the reasonable presumption that they lapped over on the underlying gneisses and igneous rocks of the mainland and the extreme western end of the island, gently sloping from their inner margin seaward, as they still do in the coastal plain south of the glacial district.

The fact that, wherever these older clays are now seen in the cliffs and exposures about the north shore of Long Island, they are involved in folds and disturbances with the earlier glacial gravels and sands is evidence that they have been disturbed during Pleistocene time by the same agency which produced dislocations in the earlier glacial deposits. Since they have been thus displaced, their present relief can not be taken as evidence of the form of the land surface on which the glacial deposits were laid down. It is even uncertain whether the depression known as Long Island sound had any existence prior to the disturbances in which these clays were involved in Pleistocene time. Everywhere the existing relief of these clay masses above sealevel is a function of their displacement. The entire absence of any relatively hard or resistant layer in the series makes it even doubtful if the seaward migrating outcrops of the Cretaceous series presented at the time of the first ice invasion, anywhere along the line from Cape Cod or Nantucket westward to New Jersey, anything like a bluff or inface of strata overlooking the bared, hard rock terrane on the north, such as might be expected were the rocks of a firmer character or of greater lithologic variety. At most, where these older clays now rise highest in dislocated masses, it may be that remnants of the old coastal plain, similar in origin to the highlands of Navesink on the New Jersey coast, stood up on the interstream areas. The deep reentrants of the northern coast, as in the case of Hempstead bay, appear to be features of Pleistocene date, across whose site the Cretaceous clays previously extended unbroken. In short, no definite trace of an older detail of land surface is now discernible beneath the glacial materials within the limits of this report. The absence, however, of deposits intermediate in date between the older Pleistocene and the ancient clays warrants the supposition that at least the northern part of the island was an area of erosion by ordinary meteoric agencies.

Beneath the Cretaceous and Potomac clays should come the hard rocks exposed on the mainland. These hard rocks in the form of gneiss appear at the surface westward in Long Island City and have been met in borings in Brooklyn. The precise depth at which they occur beneath this area is at present a matter of conjecture.

The entire absence of hard rocks in fixed ledges or outcrops within

the limits of this part of the island naturally precludes any observation of glacial striae indicating the direction of local ice movement. The ledges of gneiss in Long Island City bear striae whose direction is s. s. e. and presumably a similar course was followed over this tract.

## Glacial formations

The glacial formations of this area are divisible into two great groups: those of an unassorted, unstratified structure, composed of mixtures of boulders, pebbles, sand and clay, frequently, when covering the surface, with a knob and basin topography, forming in general terms till, or boulder clay when boulders are mixed with clay; and those composed of gravels and sand with a stratified structure showing their evident deposition by running water.

Till constitutes the larger part of the ridges or moraines already described. Boulder clay occurs as a thin layer in the bluffs on either side of Hempstead harbor and in the area between Searington and the main ridge near Lake Surprise. Ordinary till, largely in the form of scattered boulders, covers the terraced plains and the ridges and valleys north of the main moraine. The rest of the area is largely composed of gravel and sand with local deposits of blackish or bluish black clay not certainly of glacial origin and perhaps to be regarded as of Tertiary or older age. Gravel and sand constitute by far the greater portion of the glacial deposits both as regards the surficial extent and cubic contents of the Pleistocene.

Since these deposits appear by their structure and relations to have been deposited in succession, some till having been made under the ice or at the ice front while gravels and sands were being laid down by water running through or pouring out of the ice, it will be necessary to consider them in the order of their development in time. In the chronologic succession, the glacial deposits exhibit three marked phases of Pleistocene history in this area: 1) a group of older gravels and sands with an intercalated till bed, the evident equivalent of the Columbia formation; 2) the moraines and their attendant stratified gravels and sands, forming the topographic details of the surface; 3) between these deposits in the order of time, evidences of erosion by other than glacial action, which demand separate treatment.

**Columbia formation.** The rude terraced plains lying north of the main moraine on the Oyster Bay quadrangle are but the surface of a thick series of gravels and sands on which the moraines have been heaped. The reasons for referring to them heretofore as older Pleistocene may now be set forth, together with the evidence in favor of referring them to the Columbia formation of McGee,[1] the group to which the deposits appear to have been referred by that author in 1888.

F. J. H. Merrill, following the pioneer work of Mather, pointed out in 1886 that these gravels and sands under the name of "gravel drift" underlie unconformably the moraine, and concluded that they were deposited by swift currents carrying along fine and coarse materials together.[2]

The deposits as exposed on the Oyster Bay quadrangle consist of water-worn gravels and sands, clearly divisible in certain sections into an upper and lower series by a thin bed of glacial boulder clay. It has not been possible in the course of the present survey within the area to determine whether or not the group thus defined is to be divided into an earlier dislocated and a later undisturbed series, but it is clear that many sections of these gravels, along with what appears to be the boulder bed named, have been dislocated along the north coast of the island. On Marthas Vineyard and Block island such a division has been made out,[3] but the boulder clay parting, on the other hand, has not been found there in the position of an intermediate conformable bed.

The gravels consist of water-worn fragments of quartz derived from veins, granite and gneiss from the ancient Piedmont terrane of the mainland, of silicified fossils from the metamorphic Paleozoic limestones of the mainland, cherts of the same origin, and ferruginous sandstones and fragments of concretions from the underlying Cretaceous or Potomac section.

[1] McGee, W J. Three formations of the middle Atlantic slope. Am. jour. sci. Ser. 3. 1888. 35 : 367–88, 448–66. It has not seemed possible at present to establish a satisfactory comparison of the deposits in this portion of Long Island with the formations recognized in New Jersey by Prof. Salisbury.

[2] Merrill, F. J. H. N. Y. acad. sci. Annals. 1886. 3 : 341–64.

[3] Woodworth, J. B. Unconformities on Marthas Vineyard and Block island. Geol. soc. Am. Bul. 1897. 8 : 204–11.

Quartz pebbles predominate in this formation, particularly those stained yellow by the oxid of iron; hence the term, "yellow gravel," which has been sometimes given to it. This discoloration will be treated more at length later. White quartz pebbles are not uncommon, pebbles which appear never to have been stained. The silicified fossils and cherts are relatively rare, but search carried over a few square yards of surface in any gravel pit in the formation north of the moraine will usually reveal two or three of these erratics. The gneissic and granitic pebbles are at least in the mass of the formation not much decayed. On the whole, the materials are like those in the moraine and in the gravel and sand terraces on the mainland except for local staining by iron oxids. The comparison with the moraines is perhaps hardly just, because the moraines are locally largely composed of rearranged drift from these same beds, as in Harbor hill. The inference from the sands and gravels is that they are of glacial origin, modified by the work of running water, either ice-born streams or extraglacial waters. This conclusion as to their glacial origin amounts to a certainty when the intermediate boulder clay bed is taken into the account.

That the beds extend southward beyond the Harbor hill ridge or moraine can hardly be questioned; but it is difficult to distinguish the formation in front of the moraines from the later gravels and sands washed out from the ice front. At one point in the mounded drift southwest of Roslyn an exposure by the roadside of a coarse cobble bed with yellow pebbles contains also iron stone concretions which have evidently not been rolled, showing that they are probably in place, though loosened by exposure to surface actions from the surrounding pebbles. Beds of this character are found at the base of the Pleistocene on Marthas Vineyard in the Gay head section,[1] where the origin of the concretions is clear. The concretions arise from the erosion of light colored clays of the underlying Cretaceous or Potomac beds and their deposition with the coarse gravels as pebbles permeable to percolating water charged with iron salts. Cementation takes place by deposition of iron oxids around all of the pebbles, involving the outer part of the clay

[1] Woodworth, J. B. Geol. soc. Am. Bul. 1897. 8 : 205–6.

pebbles, which becomes converted into a hard stone layer, the inside remaining usually unconsolidated. When in after time these nodules are wrested from the bed in which they originate, they are broken open, the clayey or sometimes sandy interior washes out and there is left a potlike, hollow pebble of the kind known as aetites or eaglestone.[1] Hundreds of these nodules were dragged out of their bedding places by the advance of the ice over the Columbia at the time of making the terminal moraine on Marthas Vineyard and in portions of Long Island.

The occurrence of these nodules at the locality mentioned affords evidence that the underlying white clays and sandy clays were eroded at the beginning of Columbia deposition. The unconformity thus inferred is widespread to the east on Marthas Vineyard and Block island and along the Atlantic coast southward to the vicinity of Washington. Of direct local evidence, little can be said. On the shore north of Coldspring the gravelly beds at the base of the tilted Pleistocene series may be seen resting on the Cretaceous and older clays, but there is no observed difference of dip, though the absence of identifiable Eocene or Neocene beds is proof of an unconformity. No clearer fact than this was gathered from the similar sections about Glen Cove and Glenwood.

Aside from this unmistakable instance of older gravels lying outside of the moraine, it is uncertain to what extent the older beds make up the frontal plain. Yellowish gravels abound in the road and railroad cuts, but the yellow quartz pebbles have invariably been washed and worn since they were stained, and similar pebbles are now working their way from the cliffs down the beach slopes into the deposits now making along the coast. It is to be inferred, however, from the attitude and thickness of the Columbia north of the moraine that a large part of the section south of the moraine is composed of these beds.

The structure of these beds is revealed in only a few pits and coastal sections. The most extensive exposures in 1900 were found in a number of sand pits on the west shore of Hempstead harbor. In these pits the beds are horizontal, and the boulder clay bed is clearly traceable.

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[1] Geikie, A. Textbook of geology. 3d ed. 1893. p. 146–47.

Plate 2

H. Ries, photo.

View showing boulder bed and some of the stratified sands and overlying gravel, King's pit, Hempstead Harbor

A borrow-pit in the southwestern part of the village of Oyster Bay showed beds dipping southward 26°, an angle not far from that of fore-set beds in delta structure. These beds were overlain by other sands in horizontal beds, and the whole appears to be a portion of the normal section of the lower part of the series. This section lies between 40 feet and 50 feet above sealevel. There is nothing in the attitude of the beds at this locality to indicate that the strata were disturbed after deposition, as is the case on the contrary in so many of the bluffs along the north shore. Another good exposure occurs in Cooper bluff between Oyster Bay and Coldspring harbors, in the cliff on the south side of Oak neck near the wharf, and at Barker point.

*The boulder clay bed.* In many of the coastal sections on the north shore an unstratified mixture of pebbles, sand and clay in a bed varying from 3 to 10 feet in thickness may be seen in a position to indicate that it is interstratified with these older gravels; but it is only in the sand pits on Hempstead bay that a bed of this character is fully revealed. About half way up the bluff, or about 100 feet above the bay, there is a bed of boulder clay from 2 to 3 feet thick, traceable in all the pits open in 1900 south of Bar beach. The matrix of this bed is an unctuous dark blue clay locally sandy or gravelly. Scattered through it and sometimes in close contact with each other are glaciated boulders often over 1 foot in diameter and numerous pebbles attesting the glacial origin of the deposit. Several large boulders examined in 1901 by Dr F. J. H. Merrill and the writer were recognized by the first named as having been transported in all probability from the Adirondacks. Other small boulders carrying Silurian fossils indicated their origin in the Hudson valley north of the Highlands. The longest journey made by these materials appears to exceed 200 miles.[1]

The bed rests evenly and smoothly on the underlying gravelly sands without marked disturbance or erosion. This relation to the underlying bed suggests the dropping of stones and clay from overlying floating ice more than the actual advance of an ice sheet on this part

[1] Mather reported finding in the valley of Schoharie kill, boulders with "opalescent feldspar like that of Essex county" and referred them to parent ledges in the eastern Adirondacks. Geol. rep't. 1843. p. 187.

of the area of the Oyster Bay quadrangle at this time. The thinness of the bed, and the identity of the sediments which underlie and succeed it, go far to show that this boulder clay making was but an episode in the formation of the gravels and sands in this field.

The outcrop of the boulder clay bed on the bluffs gives rise to boulders which have slidden down the slope. A section transverse to the face of the bluff in one of the pits showed an ancient talus of boulder clay extending down to the road. Not only the texture and structure of the sands and gravels, but also the appearance of the boulder clay bed in these pits indicates that these deposits extended eastward across what is now the bay to the like deposits on the opposite bluff. Nowhere do the deposits show that increasing coarseness toward their exposed edges which is the characteristic mark of the heads of glacial sand plains and those bodies of glacial sands and gravels which have accumulated about the edge of a glacier or its outlying stagnant masses. The bays are clearly valleys of erosion cutting through both the Pleistocene and locally the pre-Pleistocene clays and sands alike.

A bed of till, presumably an extension of that above described, occurs on the east shore of Hempstead bay in Glen Cove about 60 feet above sealevel, in the following incompletely exposed section.

PLEISTOCENE SECTION IN GLEN COVE, FROM TOP

| | | |
|---|---|---|
| Gravel and fine sand | 3 ft | |
| Till, with small angular boulders | 5 | |
| Gravel, clayey | 1 | 6 in. |
| Gravel, sandy | 3 | |
| Sand, base not seen | 3 | |

20 feet distant the till passes into stratified gravel and sand. The rapid transition of the till into stratified drift at this locality explains the absence of the bed in many sections. It was probably locally deposited.

A similar till bed distinctly less bouldery but equally amorphous, is exposed in the bluff at Barker point, from which, first appearing at about 20 feet above the sealevel, it sinks, on the western face of this headland, southward, being involved in the dislocations of the north coast of the island (fig. 2).

Plate 3

H. Ries, photo.

King's sand bank, Hempstead Harbor, showing boulder bed between glacial gravels and sands. The boulders piled in foreground have been taken from this bed.

A small exposure of a bed of till also existed in the summer of 1900 near Rocky point at the northwestern extremity of the so-called Center island in Oyster bay. The annexed sketches illustrate the varying conditions seen at this locality. In fig. 3 the beds in the bluff west of Rocky point show again the transition from till to stratified beds. A detail of the western part of the section is given in fig. 4, showing loesslike sands at top, inclosing boulders, beneath which comes a bed of gravelly sand from 6 to 10 feet thick, with pockets of clay. A gravelly till 10 feet thick underlies this bed, below which again appear compound gravels and sand. Near the headland underlying blue clays rise up in a knob, with sands cut off on the east, the whole being overlain unconformably by till with boulders up to 2 feet in diameter. At the headland on the southwest, the sections shown in fig. 5 and 6 exhibit an earthy gravel (as in fig. 6) evidently a phase of the till bed or the till as in fig. 5, resting unconformably on tilted yellow sands, which in turn repose on disturbed clays.

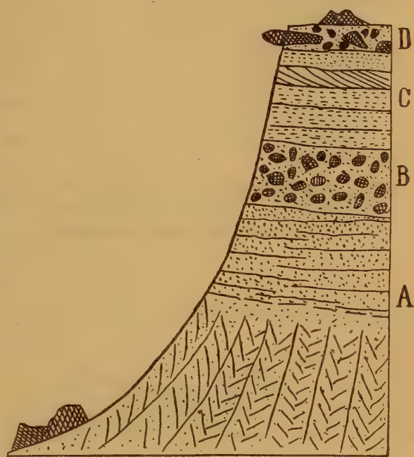


Fig. 2 Southwestern face of Barker point. A, cross-bedded ferruginous sands; B, the till bed 5 or 6 feet thick, resting unconformably on the sands, and overlain by sands; C, sands; D, surface till and boulders, the fine materials being largely rearranged sands


Fig. 3 Section along the bluff west of Rocky point. *a*, clay exposure· B, till; *c*, sands and gravels; *d*, partially buried surface boulders

Above these exposures on the shore the ground rises on the eroded and till-covered slopes of the Columbia. The evidence of unconformity between the till bed and the underlying disturbed clays and sands is in sharp contrast with the sections on Hempstead bay and

admits a different interpretation, one favoring the dislocation of the section before the deposition of the till but on a scale quite admissible as the work of a glacier. The dislocated beds dip at high angles to the south. The underlying blue clays weather whitish, carry quartz pebbles and slight traces of black carbonized plant remains and are presumably Potomac or Cretaceous. They are unconformably beneath the sands.

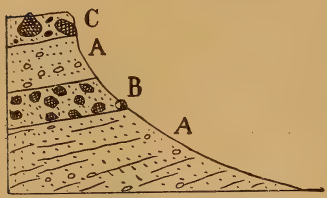


Fig. 4 Detail of section just west of preceding section. A, sands and gravels; B, till; C, loesslike sands inclosing boulders

Another dislocated section affecting sands underlain by clays occurs at the southern end of Center island (fig. 7). The clays are here dark blue, well laminated, and pass by gradations into the overlying sands, recalling many sections on Cape Cod bay in Massachusetts. The upper part of the sands carries boulders; the whole may well be a basal portion of the Columbia. At one point a small fold overturned southward has passed into a reverse fold-fault. Viewed as an overthrust, the movement has been northward. To accord with the hypothesis of glacial thrust acting from the north, it is necessary to suppose that underthrusting has taken place.

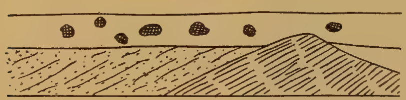

Fig. 5 Local section at Rocky point showing deformed blue clays and banded sands, unconformably overlain by till with boulders up to 2 feet in diameter, passing laterally into stratified gravel

The railroad from Oyster Bay to Roslyn passes through three deep cuts in an eastwest valley in Mill Neck. In the cut nearest Oyster Bay, whitish to pinkish sands, probably Cretaceous, appear at the bottom, succeeded by about 30 feet of coarse gravels, ill stratified and

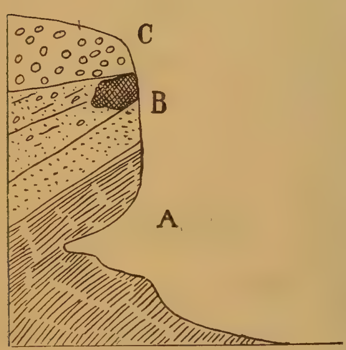


Fig. 6 Section at headland on southwest of Rocky point. A, clay; B, yellowish sandstone, with boulders; C, earthy gravel

Plate 4

H. Ries. photo.

Near view of boulder bed in King's sand bank, Hempstead Harbor

overlain by at least 20 feet of clayey sands passing above into cleaner sand. These beds dip gently east.

The second cut west shows more of the white sands, dip uncertain, overlain by glacial gravel with small boulders. The third cut west exhibits cross-bedded, white clayey sands, presumably Cretaceous, overlain by 10 or 12 feet of glacial gravels and sands with small boulders. The section shows no dislocation.

In the first of these sections the measured exposure is evidently a part of the Columbia; in the second cut, the glacial gravels mantle the eroded surface of the pre-Pleistocene series, having been deposited subsequently to the deformation and gullying of the beds. These top beds, by their boulders and lack of stratification, as well as their relation to the eroded clays, evidently pertain to the last drift. The sections show, however, that the Columbia mantles over and is wrapped about masses of the pre-Pleistocene series, as previously stated on p. 622. Similar partial sections occur on Great Neck near Manhasset.

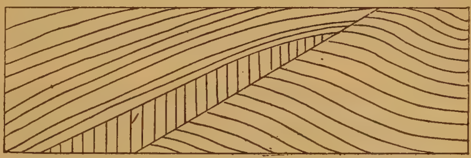

Fig. 7 A fold-fault in clays at southern end of Center island in Oyster Bay harbor

In the sand pits northwest of Port Washington, the pre-Pleistocene clays are also involved in folds, giving rise to a structure, the upper member of which is a gravel and sand bed of the Columbia formation, itself clearly older than the sands of the Port Washington delta yet to be described (p. 646). In this instance the axis of the anticlinal structure lies north and south, and the dislocation may be of a relatively late date, even so late as the time of formation of the delta named, when the ice lay deeply embayed along the north shore of Manhasset neck and when an easterly movement in the mass might be expected, since the ice at this locality was on the eastern margin of a glacial lobe at the mouth of the Hudson valley.

The deposit of sands and fine gravels forming the tabular hillock whose frontage on Manhasset bay near Port Washington is known as Tom point is a unique example of the deformation and erosion of

the Manhasset sands. The deposit, now largely removed for mason's supplies, exhibits a strong flexure with a downthrow to the south. On either side of this flexure the beds are horizontal but those on the north belong stratigraphically below those now on the same level but on the south of the flexure. The annexed cut (fig. 8) as sketched from a photograph exhibits the sand beds in the top of flexure. The truncation of the flexed beds at the present surface is sufficient evidence of the erosion of the whole to its present level. A few small glacial erratics occur on the surface, but the ice sheet appears to have swept over it without leaving other deposits. The top sands have lost their stratification but it is impossible to say how far this disturbance was due to the ice sheet and how much has been done by the growth of plant roots in the subsoil.

The small heads of Cretaceous clay appearing above sealevel on the shore of Manhasset bay, where the older Pleistocene is essentially horizontal, along with the protruding masses of these older clays in the massive portions of the section, indicate a relatively early dislocation of portions of the pre-Pleistocene basement of the island. It would therefore appear that the dislocations were not all of the same date in this portion of the island, ranging in age from at least the oldest Pleistocene to the time of the main moraines, certainly none of them are later than the Port Washington stage.

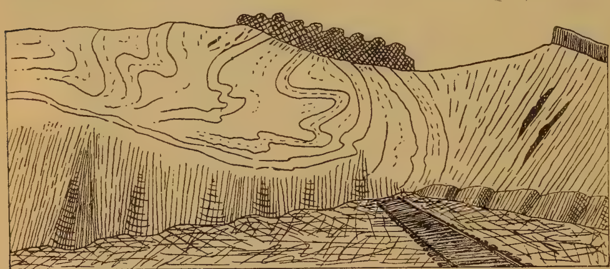

Fig. 8 Southward dipping flexed beds in Manhasset sands at Tom point near Port Washington, showing eroded surface

The upper limit of the Columbia accords roughly with the hight assigned to the plains described as lying north of the inner moraine, that is to say, the deposits are approximately delimited by the 200 foot contour line. Where lower, they have been eroded; where higher surfaces exist, later glacial drift, usually till, is found cover-

Plate 5

H. Ries. photo.

King's sand bank, Hempstead Harbor. Group of boulders which have fallen down from the boulder bed. The latter is seen in upper portion of view and some boulders are to be seen in place.

ing them. If then, we reconstruct the cross-section of the formation, it would appear as a wide belt of gravels and sands declining southward to the sea and rising with a cuestalike bluff from the sound on the north.

In ordinary nonglacial, coastwise beds, such a bluff would indicate the retreat of the beds, extending originally north to an overlap on the mainland, to their present northern limit. But in the case of glacial deposits laid down about the border of an ice sheet, it is highly probable that the beds never thinned out landward to an overlapping series on the ancient gneiss of the region beyond the sound. Somewhat similar glacial gravels and sands of the last ice epoch, on Nantucket, end abruptly on their northern or iceward margins in bluffs overlooking lower ground once occupied by the basal portion of the ice sheet against whose mural front they were laid down.[1] Upham[2] has expressed his belief in the origin of these gravels and sands in this manner, differing only from the view here set forth in that he supposes the beds to be essentially contemporaneous with the moraines which rise above their level.

It is evident that these Columbia beds, exposed in the bluffs and rude terraces along the north coast of the island, may once have extended much farther to the northward, but how much farther into the area of the sound is not now definitely determinable. Their occurrence on the Connecticut mainland has not as yet been reported, and till that area is carefully studied with this problem in mind, it can hardly be satisfactorily settled. The same indefinite answer is elicited from a study of the equivalent beds on Block island and Marthas Vineyard. In other words, the precise position of the ice front and terminal moraine of this earlier ice advance is unknown, though it could not have been many miles north of the inner limit of these gravels and sands with their intercalated bed of true till.

Aside from the disturbances above noted, two classes of changes have affected these beds since their deposition: 1) the discoloration of the beds by local and secular chemical changes in the iron-bear-

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[1] Curtis, G. C. & Woodworth, J. B. Jour. geol. Chicago, 1899. 7:226-36.

[2] Upham, Warren. Glacial history of the New England islands. Am. geol. 1899. 24:79-89, with bibliography, p. 89-92.

ing content of the gravels; and, 2) the erosion of valleys and harbors in its mass prior to at least the last till deposits on the island. The latter phenomena are so extensive as to indicate a considerable lapse of time for their production.

Discoloration of the gravels by the yellow or hydrous sesquioxid of iron has taken place to a variable extent, sometimes affecting less than a cubic foot of the materials and in other places, particularly beneath the moraine, changing the entire appearance of the section there exposed.

Local discoloring by the yellow oxid is frequently seen in the gravel pits on the west shore of Hempstead bay, wherever some iron-bearing pebble has oxidized and hydrated, the iron salts spreading outward and mainly downward through the action of infiltrating rain water. The sands and gravels above the till bed mainly exhibit this change.

Widespread discoloration of the gravels to a deep yellow occurs in Roslyn in the bluffs on the east side of the town below the base of the moraine. This deeper and more thorough coating of the gravels in this locality is a natural result of the lixiviation of the ferruginous rocks in the overlying moraine, the products of whose oxidation and hydration have worked downward into the porous gravels beneath.

The discoloration is therefore a change which is probably secular and in progress. That it had already advanced very far before the moraines were formed is indicated by the abundant occurrence in the moraine of yellow, stained quartz pebbles; but these pebbles in the moraine are usually not in the place in which they were originally stained, for they have water-washed surfaces. The staining was accomplished while the pebbles lay in an earlier deposit, either the Columbia or some unexposed member of the ancient coastal plain.

**Erosion interval.** The evidence of late dislocation on a small scale commensurate with the pushing and dragging action of a great ice sheet, the spreading of till and boulders over the surface of the Columbia, and the amassment of heaps of drift evidently in part derived from the surface of the deposit, afford indubitable evidence of the degradation of the formation to some extent by ice action subsequent to the completion of the series of deposits. But

Plate 6

H. Ries, photo.

Sand washer, King's sand bank, Hempstead Harbor

the surface of the formation north of the moraine is carved into valleys and deep reentrants of the coast line, depressions the main features of which are consonant neither with the southward movement of ice over the area nor the erosive work of subglacial streams discharging across them at the ice front. That these valleys antedate the last ice advance appears to be shown in that all of them are more or less encumbered by morainal materials.

As typical examples of these valleys, that entering into Manhasset bay at Glen Cove, as well as that in whose lower extension Mill Neck creek flows, may be taken. The Glen Cove valley heads at the inner base of the moraine near a very well marked pass at the eastern base of Harbor hill, a passage through which undoubtedly subglacial waters escaped when the ice front lay against the moraine and at a time when it must be admitted subglacial drainage may well have followed the course of this valley for a part or a whole of its course. The objections to accepting the valley, however, as the work of this subglacial stream, aside from those above stated, are 1) the graded character of its bed, sloping northward toward the sea as if made by a normal stream like that now flowing in it, though the existing stream evidently flows in a valley which it found encumbered by more or less glacial drift; 2) the tributary vales evidently cut by running water as in normal open air streams; 3) the course of the stream at Glen Cove, east and west, in a direction contrary to ice movement in this locality. The digitation is even more pronounced in the case of the Mill Neck creek valley just south of the ponds. The upper part of the valley above the 100 foot contour is also walled in by glacial deposits later than the Columbia in which it is cut. Like considerations hold in regard to the deep valleys which extend from Oyster Bay village toward East Norwich. The Mill Neck creek depression continues below sealevel, and, branching south of Oak neck, separates that island — an island except for the barrier beach tying it to the land on the west — from Mill Neck. It is evident that there has been developed a marked dissection of the Columbia, and that this dissection on north and south as well as on east and west lines is increasingly severe toward the northern coast, as in the normal degradation of an area of incoherent materials marginal to a depression such as that of

Long Island sound. The inference is that at a time immediately before the last advance of the ice the area was exposed to ordinary stream action opening out valleys on the gravels and sands, the mouths of these streams reaching the sea below the present sealevel.

There are other evidences, however, which show that ice action has considerably modified and enlarged certain of these valleys. Such enlarged valleys constitute the bays and harbors of the north shore. These harbors have their bottoms 27 feet below sealevel in Hempstead bay, 61 feet in Oyster bay and 33 feet in Manhasset bay. This depth in each case is probably less than the original depth of the depressions, for there has been some infilling by glacial deposition — probably small as judged by the filling in of valleys extending above sealevel — and some infilling through post-glacial deposition by tides and currents. Arguments for the excavation of these embayments subsequent to the formation of the Columbia gravels and sands have already been given on p. 628. Homologous depressions occur eastward on this island in Coldspring and Northport harbors. They are also found on Marthas Vineyard in Lagoon pond and Menemsha pond, and on Block island in Great pond.

As to the period of this valley-making, excepting the modification and enlargement by ice action, it is clearly older than the main or inner moraine at Roslyn, a deposit believed to be equivalent to the Cape Cod moraine. Whether the stream erosion preceded or followed those fragments of an older moraine which on this sheet mark the western extension of the outer or Nantucket moraine, appears to be locally undeterminable, because the two sets of phenomena are not found in association. If a comparison with Marthas Vineyard and Block island holds good, the erosion of the valleys should be here as there anterior to both moraines. In all of these New England islands, the valleys do not occur as such on the south of the moraines, because that area has been buried beneath the outwash plains of the first or outer moraine on the eastern islands and of both the first and second, or inner and outer moraine on Long Island.

The time involved in the excavation of these valleys is indeterminate. They are largely excavated in gravels and sands of a porous structure. Much of the existing rainfall passes through the

deposits where clays do not occur, finding its way out near sealevel in springs, as in the village of Oyster Bay. At best, surface streams would have cut but slowly on these deposits, as they do now, the excavation in post-glacial time being practically nothing in the form of mechanical abrasion.

The share which the ice and the subglacial streams may have had in the excavation of the harbors, is discussed in connection with the moraine on p. 643.

**Wisconsin epoch. Moraines and attendant sand plains.** The existence of two lines of moraines in this area has already been set forth in the account of the topography. Both of these deposits are largely composed of materials which have been water-worn, in this feature reflecting the nature of the terrane from which the materials were eroded and on which they were deposited. The ice sheet on leaving the bed rocks of the mainland and the north shore of what is now Long Island sound passed over the Columbia gravels and sands, gathering debris from these older water-worn deposits; hence the water-worn pebbles which abound in the moraine even when the materials are truly ice-laid without stratification. True boulder clay occurs in small patches, but much of the till is sandy, and even in its coarser phases often exhibits traces of water action closely followed by a shoving of the deposits into contorted drift.

The outer deposits consist of a few low knobs rising like kames from the surrounding gravels. They bear a few boulders on their surface and frequently in road cuts reveal a thin patch of till. West of Searington rolling surfaces of till composed of a gravelly boulder clay give the deposit, along with its steep southerly front, something of the aspect of the main moraine as it exists southwest of Lake Surprise. These knobs and their rare attendant basins have a much less strong development than those heavier accumulations which lie in the form of a strong ridge immediately north of them. The deposits do not afford in themselves precise indexes of the position of the ice front at the time they were made. They appear to be submarginal deposits laid down when the ice front lay somewhat to the south of them, and are best compared with the kame moraine in the eastern part of Nantucket.

The inner or main moraine exhibits likewise the two phases of

building by the direct action of the ice and through the accumulation of gravels by water action.

The till phase of the moraine in this area is best shown in a road cut about one mile south of East Norwich. The till is here decidedly gravelly rather than clayey, with cobbles up to 20 inches in diameter, rarely, though occasionally ice scratched. The topography is cast into small knobs more distinct than the 20 foot contour lines of the map can be made to show. The hill over which the road in question passes has a drumlinoid curve, as if the ice had overridden it.

The overriding action of the ice shown in the boulders deposited on water-worn gravels in the moraine and by the ice-swept curves of many of the knobs is further attested by the outlying meridional ridges between the inner and outer lines of moraines just north of Westbury pond. Their massiveness and accordance in elevation with the inner ridge are good evidence that they were formed by the same phase of ice action which was concerned in the construction of the main ridge of which they are but spurs.

The thick till phase of the moraine proper shades off imperceptibly into the thin till phase of the upper surface of the gravel plains on the north. This latter drift appears to be, over most of the area, ordinary ground moraine like that on the mainland far north of the moraines. Only here and there and particularly on the extreme eastern border of the Oyster Bay quadrangle do considerable patches of till with morainal topography lie north of the main wall, but none of these have the aspect of a frontal deposit. They are, rather, thickened deposits of the ground moraine, and their principal relief is molded on the ridges and valleys of the older drift which they mantle. They have therefore on the map been distinguished from the deposits which by their linear arrangement and massiness more clearly pertain to deposition at or immediately beneath the ice front.

The stratified gravels in the moraine appear to belong to two distinct categories as regards the mode of their origin: 1) outwashed gravels laid down at the ice front and subsequently pushed up into ridges; 2) high cones or fans deposited along the ice front by outpouring streams either from fountains such as Russell has described

on the Malaspina glacier; or 3) deposits made in water-eaten cavities in the ice front. As a rule, the gravels are seldom so well exposed as to reveal the structures on which a decision as to their precise character can be arrived at; and their origin in the presence of the ice in all cases being so intimate as to permit the falling of erratics on their surfaces makes it difficult to discriminate them from the gravelly till. This is particularly true where the growth of trees and the overturning of the superficial deposits have broken up the original stratification in the surficial portion so that the materials have the structural appearance of till or at least ice-deposited gravels. The deposition of the surface gravels by direct ice action is sometimes shown by the scratches on hard silicious pebbles. These scratches are usually miscroscopic and would have been quickly effaced by water action. Such pebbles occur in the churned up gravelly drift on the surface of the Columbia north of the moraine. The structure of the principal knob in this moraine chanced to be revealed in the summer of 1900, and the following notes on Harbor hill show the surprising development of these water-worn gravels in the deposit.

*Harbor hill.* The precise mode of accumulation of the materials in the terminal moraine still demands explanation in numerous details, particularly in regard to those portions which are mainly composed of stratified gravels and sands. Nowhere in the moraines on the islands off the southern shore of New England does this problem become more urgent for a satisfactory answer than in Harbor hill, a towering mass of stratified gravels, forming the culminating point of the moraine on this quadrangle at the eastern side of the pass through which the glacial drainage escaped from Roslyn bay to the great south plain. This hill rises with steep slopes into four knobs, the highest of which has an elevation of 391 feet, its base on the outwash plain being roughly circumscribed by the 200 foot contour line.

At its eastern base, the hill is separated from the extension of the morainal wall in that direction by a distinct depression, or trough, one of those numerous channels which gave exit to the intraglacial waters on to the outwash plain. On the west, its slopes fall off to sealevel at the head of Hempstead harbor. The high

point named is composed of stratified gravels and sands with yellowish layers, dipping nearly flat on the north side of the summit but inclining to 30° south, and evidently truncated on the west. This section was exposed in June 1900 in the excavation for a large house then in process of erection. Other small sections in driveways along the western slope exhibited stratified beds dipping in places 5° northward and usually eroded. On the western slope bouldery till, reddish from oxidation, appears about 5 feet thick; but till is wanting over the summit, which evidently has not been run over by the ice.

A complete section through this hill would be required to satisfy the needs of an exact analysis of its mode of formation; but the gravel beds dipping 30° south at the summit on the southern face of the knob appear clearly to place it in the group of glacial cones, formed along the ice front, homologous to the alluvial cones which form in the lower course of a drainage furrow on the side of a mountain valley, with this difference, that the mass at whose base it was formed, being ice, has melted away.

The glacial gravel in these cones and mounds arranged along the ice front, would appear to have been washed off from the top of the thinning ice border or to have issued from tunnels in the upper part of the ice. The character of the material in Harbor hill gives a decisive clue to its origin. The gravels are mostly yellow quartz from the older Pleistocene deposits which flank the moraine on the north. They probably have not been transported for distances greater than 10 miles; they may have been caught up from the base of the ice within 3 or 4 miles. At all events, they are locally derived material already existing in the district when this advance of the ice was accomplished.

The elevation of Harbor hill, nearly 400 feet above present sea-level, affords conclusive evidence as to the least estimate which may be made on the hight of the ice front at this point. This hight was at least 400 feet and probably more. This least elevation agrees well with the data found by Smock[1] in the longitudinal valleys of northern New Jersey, where ice tongues rose northward for a few

[1] Smock, J. C. On the surface limit or thickness of the continental glacier in New Jersey and adjacent states. Am. jour. sci. 3d ser. 1882. 25:339–50.

miles at the rate of 30 feet to the mile. Such an elevation of the ice sheet increasing northward over the sound and on the mainland would give great hydrostatic pressure to the subglacial drainage, the effect of which would be to produce violent discharge at the front in any direction, outward or upward, in free coursing streams on the one hand and in fountains along the crevassed, drift-blocked ice margin on the other hand, in the manner of the discharge from the border of the Malaspina glacier as described by Russell.[1] An overladen stream, scouring the gravelly bed of the glacier and rising at the front through a shaft to a point of discharge on the margin, would drop that material at the margin in a high cone, whose ultimate form would depend on the degree to which it was deformed by irregular deposition on buried masses of ice, the melting of which would let down those huge kamelike heaps of gravel in the form of mounds along the ice front.

*Distinction between outer and inner moraine.* Two very distinct lines of moraines, designated as the inner and the outer, typically developed on Cape Cod on the one hand and on Nantucket and Marthas Vineyard on the other, have long been recognized by American geologists, and have been traced with much certainty across the intervening stretches of sea and land or islands to Long Island, most successfully by Warren Upham,[2] whose name and labors must ever be associated with the glacial deposits of this region. Mr Upham evidently regarded the inner of these two lines of moraines as terminating, so far as its relief above sealevel is concerned, at Port Jefferson. The morainal ridge which extends from the vicinity of Coldspring to New York narrows was regarded as the outer moraine. This interpretation has, so far as I know, ever since been generally accepted,[3] and the moraines have so been represented on compiled maps, leaving as an unsolved problem the question of what has become of so well defined a moraine as that which from Port Jefferson eastward has been known as the inner moraine,

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[1] Russell, I. C. Second expedition to Mt St Elias. U. S. geol. sur. 13th an. rep't. 1893. pt 2, p. 81.

[2] Upham, Warren. Glacial history of the New England islands. Am. geol. 1899. 24:79-89.

[3] Chamberlin, T. C. U. S. geol. sur. 3d an. rep't. 1883. map, pl. 33.

a deposit which is almost everywhere in its extent more massive than the outer moraine.

The writer is led by his observations of the two moraines on Long Island to dissent from this long accepted opinion, and to regard the inner moraine as continuous westward of Port Jefferson to the vicinity of Coldspring and Syosset, where the two moraines nearly coalesce. They maintain their relative positions with some distinctness to the vicinity of Roslyn, where the inner moraine crosses the outer moraine, the latter disappearing beneath the later one, which continues onward to the western end of the island and becomes the terminal moraine of the mainland. The tracing of the two moraines made in the fall of 1900 by J. E. Woodman served to show the extension of the inner moraine to the southwest of Port Jefferson on to the eastern limits of the Oyster Bay quadrangle.

This interpretation of the westward extension of the two moraines is quite in line with the observed tendency of the ice front along the southern coast from the easternmost point in Massachusetts to the Hudson river. On the east the moraines of Nantucket and Cape Cod are at the outer margin of these two lobes more than 25 miles apart. In the region of Vineyard sound they are from 5 to 10 miles apart; they are quite 10 miles apart in the meridian of Block island; when they reappear on Long Island, they approach each other. West of Roslyn, the second moraine crosses the first. From this it is concluded that the inner moraine is not so much a recessional moraine as a frontal moraine built after a retreat from the position of the first moraine, followed by an advance to the position of the second moraine, accompanied in the Hudson valley by a greater outrun of the ice sheet than in the first advance. This overlapping of moraines is a well attested phenomenon in the region south of the great lakes.

The ice front which rested against the north coast of Long Island in the vicinity of Port Washington can not well be the same as that whose moraine caps the cliffs east of Port Jefferson. In the first place, at Port Washington the morainal accumulations are very slight indeed and do not rise in mounds; in the second place, the ice sheet halted there for a brief time only, as is witnessed by the small amount of outwash in the sand plain at that locality. This

halt is rather to be compared with those nearly stagnant ice fronts which are marked over southeastern Massachusetts and in the Narragansett bay region by similar sand plains formed in the retreat of the ice from the long maintained frontage on and against the Cape Cod moraine, a stage everywhere on these islands marked by well developed outwash plains.

*Glacial streams.* The course of glacial streams escaping from the ice front and extending over the frontal plain on the south side of the island is plainly indicated by the creases extending from the moraines near the head of the north shore harbors and from other passes in the main moraine. The principal of these streams seem to have followed the course of the harbors, if we may judge from the cross-section of the erosion channel or interruption of the moraine where they crossed it. The most instructive of these channels across the moraine is at Roslyn ; there is another at Manhasset, and still another less marked at the southern end of Greatneck bay.

In each of these cases the larger valleys quite up to the pass in the moraine appear to have been occupied by ice at the time the ice sheet began to melt away. The *thalweg* north of the pass or divide rises steeply, usually from the bay side, invariably much steeper than the gradient of those valleys which, elsewhere on the surface of the plains north of the moraine, have been interpreted as older than the last ice advance. The pass in the moraine north of Creedmoor at the southern end of Little Neck bay is about 150 feet above sealevel ; that of Manhasset bay is about 170 feet. The Roslyn channel is at about 130 feet. There is thus no accordance of level in these outlets.

Other passes across the main or inner moraine occur west of Roslyn at about 230 feet, and east of Harbor hill at about 90 feet. Southeast of Brookville there is a pass at about 230 feet, and south of East Norwich another at about 210 feet. All of these appear to be more or less in line with certain valleys north of the moraine, and all of them lead out south of the moraine into creases which descend to the sea.

The broad depression passing by Locust Grove toward East Norwich is not wholly erosional in origin. Just north of the road at Locust Grove the bottom descends into a large elliptic pit suggesting

the one time presence of an ice remnant. The margins of the depression also are contoured as if by deposition against a mass of ice. It is precisely in this portion of the ice front that the crest of the moraine bears indications of having been overridden by the ice (p. 638).

The transmorainal water courses are best studied at Roslyn. At this point the glacial stream excavated a trench nearly 40 feet deep in the gravels immediately adjacent to the moraine on the south, forming well defined terraces fairly well brought out by the contours on the map. About a mile below Roslyn this crease turns sharply eastward for half a mile, then straightens out and continues southward by Albertson, to the east of East Williston and thence to the sea.

The frontal plain near Creedmoor exhibits no marked trace of a crease, and many creases which are distinct on the outer southern margin of the outwash plain become faint and practically disappear as surface features nearer the moraine. This fading of creases would be caused by the wandering of streams over the surface, spreading gravel and sand, with the aggradation or building up of the plain by the streams near the ice front so long as they were overloaded with debris.

The creases on the eastern part of the Hempstead quadrangle are deflected southwestward into the Jamaica bay depression. East of that region, the streams flow generally southward, the numerous creases marked by the 100 foot contour line, for instance, gathering southward into six or seven drainage channels through which small streams now drain the water from the plain.

*Outwash plain.* The outwash plain is evidently more complex in its origin that its mere surface would indicate. The disappearance of the older Pleistocene gravels beneath the moraine on the north at about 200 feet above the sea has already been noted. Just as the level of these deposits falls off on the north side of the moraine to the westward, so does the hight of the outwash plain, and, for that matter, that of the main moraine itself. There is good reason for holding therefore that the so-called Columbia deposits extend south of the moraine and presumably underlie the outwash plain, if they do not actually form here and there surface exposures.

Yellow and yellowish gravels occur in some of the railway cuts, but it has not been possible in the present survey satisfactorily to delimit such older deposits, except in one case, that of the Far Rockaway ridge. This peculiar deposit is described on p. 651.

The materials exhibit at surface a gradual diminution in coarseness from coarse gravel near the inner moraine to fine sands at the outer limits of the plain. A shallow excavation in the county building site at Mineola exhibited alternating layers of coarse, nut-sized gravel and fine sandy gravel with feebly developed crossbeds at intervals. The pebbles were mostly white quartz and gneiss, this latter often decayed. More rarely were seen small pebbles of ironstone and a ferruginous conglomerate of white quartz pebbles. Pebbles as large as 3 inches in diameter were extremely rare.

A rather anomalous element for the upper part of the section of the plain is the brick clay found at East Williston. While clays would normally develop about the margin of a plain of this character in the sea, to be subsequently overlain by the outward growth of the thickening plain, such clays would hardly be formed with a surface so nearly that of the completed gravel plain; and it is probable that these are either an older degraded deposit or owe their position to the deformation and uplift of the basement on which the deposits and topography of the last extraglacial streams have been imposed. The section, which is exposed in a somewhat depressed, troughlike area, is as follows:

SECTION OF CLAYS AT EAST WILLISTON

| | Feet |
|---|---|
| Soils | 1.5 |
| Sand, gravelly, with quartz and granitic pebbles, locally reddened | 8 |
| Clays, sandy, with quartz pebbles | |
| Clay, sandy in yellow band | |
| Clay, blue, finely laminate, rarely with quartz pebbles, exposed | 3 |

The section is apparently conformable throughout. Crosby, if I understand him rightly, would refer these clays to the Tertiary.

The manner in which the water percolating through the sand plain north of and above the 60 foot contour in the Hempstead

quadrangle comes to the surface south of that limit and flows in small streams to the sea suggests that clays are there immediately beneath the surface veneer of sand and fine gravel.

The surface slopes seaward at the rate of about 15 feet to the mile. Aside from the drainage creases above referred to, no other lines of water action have been found within the area. The line of contact with the moraines gradually rises from west to east, very much as the elevation of the older Pleistocene increases on the north of the moraine. Everywhere the plain appears to rise continuously to the base of the moraines. The only possible exception to this statement is found in the barlike ridge which lies northeast of Hicksville; but the northern slope of this bar, much steeper on the whole than its southeastern face, is not conclusively to be compared with the northern margin of a frontal terrace plain such as that of Nantucket, in which the outwash of sand and gravel has carried the deposit up against the base of the ice front. If this deposit were of such an origin, its northern slope would fix the front of the ice at the time of the making of the outer line of morainal deposits, about half a mile in front of the submarginal moraine, and this gravel bar would somewhat antedate the part of the creased plain lying to the west.

The plain everywhere on the south sinks beneath the surface of the marsh without trace of a shore line action. So far as its present surface is concerned, it appears to have arisen by the outwash of streams in the manner of those extensive sheets of gravel, sand, and glacier mud which confront the Malaspina and other existing glaciers in high latitudes at the present day.

With the completion of the inner moraine and the sheeting over of the southern outer slope with gravels and sands creased by outrunning streams, the principal work of the ice sheet on this portion of the island ceased, and we next find indications of its front farther north along the blufflike descent to the present Long Island sound. This front is best marked at Port Washington and on the area to the westward shown on the Harlem and Brooklyn quadrangles.

**Port Washington stage.** The first definite trace of a halt in the ice front after the retreat from the main moraine is found on the northern and western extremity of Manhasset neck near Port

Plate 7

H. Ries, photo.

Section of glacial delta in Reed and Murray's sand pit, Port Washington. View from bluff above, showing fore-set beds dipping toward the south, the thin top-set beds, and the level surface of the delta at about 80 feet above present sealevel

Washington; hence the ice-laid and the water-laid drift of this episode are here assembled under the name of the Port Washington stage of ice retreat.

Whether some of the deposits lying south of this line and yet north of the moraine, as in the plain north of Greenvale station, may not constitute an intermediate series of deposits can only be determined by more evidence than the topography of the deposits alone affords.

From the village of Port Washington northwestward there overlooks the harbor a thick plain of sand with a lobate margin. These lobes point inward from the east and the north and have their summit line traced by the 80 foot contour line. The plain of sand is free from boulders, and its structure, as shown in numerous deep sand pits, consists of beds dipping everywhere southward toward the shore at angles of about 20°. All about the iceward edge of the sand plain are boulder-strewn fields, which on the north and west have a decidedly morainic topography below the 100 foot contour line. From near Plum point around the coast of the sound to Mott point this topography is very distinct, forming a rough slope to the sea rather than a ridge; but the morainal deposits, as shown at Barker point, are a mere veneer over older glacial beds.

The topography thus defined marks the overlap of the ice sheet at this stage on Manhasset neck, and the sand plain is a delta formed in a body of water whose surface was approximately at the level of the summit line of the lobate margin of the deposit.

It follows from this conclusion that, if other sand plains at this level occur to the east and west on the north side of the moraine within approximately the same distance of retreat from the main moraine, the probable position of the ice front at this later stage may be traced by drawing a line along the northern margin of these deltas.

Another such deposit less clearly developed occurs at Great Neck village at approximately the same hight; and, as the line between the inner margin of the sand plain and the ice edge on the western part of Manhasset neck turns in this direction, it appears legitimate to associate the two deposits in the manner indicated. The line thus drawn suffices to show that the front of the ice sheet was at

this time very irregular in outline as compared with the crest of the inner moraine (*see* pl. 9).[1]

As the land, on the south of the Port Washington stage, on the Oyster Bay quadrangle everywhere in the moraine rises to levels higher than 80 feet above the present sealevel but is open to the west, the nature of the body of water in which the deltas at this stage were built — whether fresh water or sea water — must be determined by observations drawn from outside the district. With this point in mind, the following notes from the Harlem and Brooklyn sheets throw light on the glacial history of this area.

### Harlem and Brooklyn quadrangles

For the purpose of comparison and in order to follow out to some definite conclusion the problems arising on the area heretofore dealt with, a reconnaissance was made of the region on the west. The questions which have thus far arisen are the distinction between the inner and the outer moraine, the nature of the water body in which the Port Washington delta was deposited, and incidentally the reason for the diversion of glacial drainage on the outwash plain into Jamaica bay.

It has been shown how the "inner" moraine becomes the principal and outer moraine west of Roslyn. From this vicinity, particularly near Hollis, to the western limit of the island the alinement of the front of the moraine at its merging into the sand plain is strikingly uniform in direction. From 2 to 3 miles east and west of Jamaica this line certainly is suggestive of an ancient shore line, now at about 80 feet above the sealevel.

A number of newly cut streets expose the glacial deposits along this line, particularly on the crest and frontal slope of the moraine in the vicinity of Jamaica. The moraine near the front is composed of till with medium-sized boulders, often passing into an ill stratified, contorted drift, with lenses of till and gravel, the topography of the whole being of the knob and basin type.

The frontal slope of the moraine inclines from 15° to 20°, an

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[1] On the colored geological map accompanying this report, the deposit at Great Neck village is not discriminated from the older Manhasset sands for the reason that no section of the deposit was obtainable.

angle rarely as steep as that of repose of sliding materials on an ancient cliff whose base has been abandoned by the sea. One such steep place a few yards in length occurs between Jamaica and Hollis.

Along the base of the slope at the inner edge of the plain, if wave action had determined the lineality of the morainal front and secondarily its slope, there is a lack of the critical evidence which one would expect to find at the place. The generally unstratified character of the deposit forming the morainal front offers little evidence as to whether it has been cut back by wave action or not, but on the west side of Prospect park in Brooklyn decisive evidence on this point is found.

West of Prospect park the morainal front maintains its lineal course toward New York narrows, but with a rather bulging frontal slope composed of stratified gravels. As seen in pits open in the season of 1900, these stratified gravels rise up steeply from the northern margin of the frontal plain, then bend downward into a large kettle-hole in the deposit, a depression marking the site of a mass of ice. The attitude of the beds suggests frontal shoving on the part of the ice sheet as well as irregular deposition; but the significant feature at this locality is the apparent absence of anything like a cut bench or cliff in the bulging front of the deposit.

The structure of the sand plain is exposed in occasional pits. The beds are prevailingly cross-bedded, showing frequent reversals in direction of the transportation of the sediments. Such cross-bedded layers occur in glacial gravels where there is no reason for supposing the sea to have acted on them.

On the east, on the Oyster Bay sheet, the inner margin of this frontal plain rises above the 100 foot contour level; in this region it sinks gradually below it, till north of the Jamaica bay depression, where the plain has a width not exceeding 1½ miles above sealevel, its hight next the moraine is only 60 feet; westward it rises slightly again. For a portion of its length, therefore, this line accords in elevation with the 80 foot level of the water body in which the Port Washington delta was built. If throughout the line accorded with the Port Washington level, it would favor the existence at that stage of a body of water in front of as well as in the rear of

the moraine. So far as can be seen, such a body of water must have been the sea, and it would be warrantable to suppose that the land stood 80 feet lower than now with reference to the ocean.

### Jamaica bay depression

The possibility of such deformation of the frontal plain since glacial times as would produce the present departure from the 80 foot level along the northern margin is negatived by the peculiar depression known as Jamaica bay, whose origin it is now necessary to consider before arriving at a conclusion concerning the submergence or non-submergence of the island at the time of the Port Washington stage of ice retreat.

The semicircular area of marshes and salt creeks forming Jamaica bay outlines a remarkable depression in the outwash plain. The moraine immediately back of it is quite as well developed as for some distance east and west of it, nor is the crest of the moraine perceptibly lower at this point, where there appears to be a lack of development of the plain. The moraine shows therefore no signs of having been depressed at this point, and was formed probably later than the depression referred to.

That this depression in the plain is a feature dating from early glacial times and an original feature in the growth of the plain is also shown by the behavior of the creases or drainage channels which lead into the bay: these creases converge on all sides toward the depression, showing that the slopes of the plain were then as now toward this relatively unfilled area. It follows therefore that the plain has not necessarily been deformed since glacial times, and that the rising and falling of the inner line of contact of the plain with the moraine is an original constructional characteristic of the deposits. If this reasoning be correct, then the local coincidence in level of the inner margin of the plain with the level of the Port Washington delta is not due to the control of a water level common to both areas.

Moreover there is reason to believe that the frontal plain was mainly developed when the ice lay along the inner moraine previous to the Port Washington stage, and, as will shortly be stated, that the Port Washington delta was deposited later in a temporary lake confined between the moraine and the retreating ice front.

Concerning the origin of the Jamaica bay depression, it is intimately associated with another feature, the Far Rockaway ridge already mentioned as extending northeastward on the southeast side of the bay till it disappears beneath the sands of the frontal plain near Lynbrook. The structure of this ridge is not well revealed. So far as the superficial deposits go, they appear everywhere to be yellowish quartz gravels up to 3 inches in diameter. Like the depressed area northwest of it, the ridge appears certainly to be older than the surface features of the plain in its vicinity.

Barnum's island, lying to the east of the Far Rockaway ridge, was not visited; but the following well section, reported by Dr F. J. H. Merrill several years ago, would seem to indicate that the Far Rockaway gravel extends in that direction. The normal sediments of the outwash plain would be, at least at surface, at this distance from the moraine fine sand rather than gravel.

WELL SECTION ON BARNUM'S ISLAND[1]

| | Feet |
|---|---|
| Sand and gravel, stratified | 70 |
| Clay and clayey sand with lignite | 56 |
| Gravel and fine sand with clayey sand | 44 |
| Blue clay, clayey sand and silt, with lignite and pyrites | 168 |

Crosby agrees in referring the upper 70 feet to the yellow gravel.

The elevation of the ridge is quite uniformly a little more than 20 feet above the sealevel; its direction is parallel with the moraine on the north of it. This association of a depression which appears to have been in the process of filling by streams pouring from the ice front, with a bar of gravels older than the outwash plain, as their composition and form show, suggests the deformation of the Columbia or some underlying coastal plain formation at some time anterior to the completion of the moraine and its frontal plain. Such deformation might well arise as the effect of the imposition of the weight of the ice sheet on the yielding sediments previously deposited. In this view, the Far Rockaway ridge is an outlying, upraised fold, or "parma,"[2] and the bay a correlated depressed area,

[1] Merrill, F. J. H. Geology of Long Island. N. Y. acad. sci. Annals. 1886. 3:350.

[2] Suess, Edouard. La face de la terre. Paris. 1897. 1:820.

both of which are an effect of the early invasion of this part of the island by the ice.

On the other hand, it is possible that this bar may be the inner margin of a stratum of these yellow gravels, the low ground north of it being the unfilled portion of a longitudinal valley but it does not seem possible at present to demonstrate this view.

### Glaciated ledges

Frontal moraines mark the position of the ice front. The motion of the ice, at least near its margin, will tend to be toward that front; hence, since the moraine in this part of the island trends to the south of west, forming a lobate line across this region and that adjacent in New Jersey, glacial striae in this part of the island should run to the east of south. A number of ledges of gneiss in Long Island City meet this requirement. One of the largest exposures of bed rock occupies a vacant lot adjoining the Queens county courthouse on the west. The ledge is heavily glaciated, forming a long, low *roche moutonnée.* The striae range in direction from 29° to 30° west (magnetic). A few striae run from n 15 w, and one set of scratches lies in a northwest direction. The strike of the foliation of the gneiss is n 25 e magnetic. Other outcrops occur to the northeast with striae running from the north northwest. A series of shallow oval depressions extends in a northwest and southeast direction across one outcrop, the whole bearing evidence of water action, presumably that of a subglacial stream.

The southeastward movement of the ice on this side of the Hudson valley is further attested by the drift. The moraine from Brooklyn as far east as Oyster Bay contains trap boulders, the nearest known site of which rock is in the Palisade trap ridge on the west bank of the Hudson river.

Stratified red sands, also undoubtedly derived from the area of Triassic red sandstones now found only on the west bank of the Hudson, occur in a section by the roadside from Corona to Astoria, being there overlain by 8 or 9 feet of gray till with trap boulders.[1]

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[1] Boulders of trap and red sandstone were seen by Sir Charles Lyell in an excavation made in a boulder bed at the Brooklyn navy yard. *See* Lyell, Charles. Travels in North America. N. Y. 1845. 1 : 189–90.

This fanning of the ice sheet to the eastward on the east side of the lower Hudson and to the westward on the west side is consistent with the form of the moraine across the mouth of the river. The axis of the lobe thus indicated has been fixed by Salisbury on the west side of the Palisade trap ridge.[1]

From what has been stated, it would appear that the western end of Long Island is occupied by a moraine and a contemporaneous outwash plain built along the margin of the ice sheet, when it had, in this region adjacent to the mouth of the Hudson, pushed a lobate mass somewhat farther south than the limit attained by an earlier stand of the ice front, marked eastward by the outer moraine from near Roslyn to Nantucket; that the frontal plain in this district rises to slightly different levels against the front of the moraine, a feature which is constructional and not due to post-glacial warping; and that the front of the moraine as a whole presents no decisive evidence of having been subjected to marine action above the present level of the sea.

With this statement of the observations bearing on the marine limit at the time of the last ice invasion, it is necessary to return to the later ice phenomena exhibited in connection with the Port Washington stage of the retreat.

## Port Washington glacial lake

It has already been pointed out that the last evidence of the presence of the ice sheet on the area covered by the Oyster bay quadrangle is found in a well defined delta and attendant ice-laid deposits occupying the semicircular tip of Manhasset neck. The phenomena indicating a halt of the ice front against this headland for a brief time subsequent to the retreat from the inner moraine at Roslyn are very clear. The conclusion having been reached that the area has not been submerged to the depth of 80 feet since the beginning of the deposition of moraines in this part of the island, it seems necessary to further examine the region to determine the possibility of this delta having been built in a temporary glacial lake.

To the north and west of Port Washington occur a number of gravel and sand pits opened in a characteristic glacial delta, whose

[1] Salisbury, R. D. N. J. geol. sur. An. rep't state geol. for 1893. 1894. p. 161.

upper surface, as indicated by the topographic map, is about 80 feet above the present sealevel. The outer, or southern edge of this delta is sharply lobate, each lobe corresponding, as in existing deltas, to the end of some distributary stream coursing in glacial times over its surface to the body of water in which the deposit was accumulating. Taking the summit line of these lobes as indicating the water level of the time, it is evident that the water body rose 80 feet above the present sealevel. We shall examine presently into the question whether this water was the sea or a lake held in on the north side of the moraine by the ice sheet which still occupied Long Island sound.

The front of this sand plain or delta is concave toward Manhasset bay, trending northward from Port Washington and then westward about one mile beyond the village. This form of the front is accordant with the outline of the outer curve of the neck. At a distance varying from half a mile to a mile from the lobes the glacial stratified sands pass into till, and the level surface of the old delta gives place to a hummocky topography, sloping generally toward the open waters of the sound, plainly indicating the deposits which were laid down in the presence of the ice or beneath it while the waters pouring from the ice constructed the delta. We thus have the picture of a small semicircular embayment of the ice front. Frôm an inspection of the ground, it appears that the edge of the ice lapped over on the existing land for a distance of three fourths of a mile to nearly a mile from Barker point, around by Sands Light point, and for a slightly greater breadth on the eastern side, at least as far as Mott point. Beyond this locality it is quite impossible to discriminate the deposits of the ice made at this stage from the earlier deposits laid down when the ice front was closely pressed against the moraine on the south.

The structure of the delta as exposed in the summer of 1900 is typically deltiform, with beds of sand steeply inclined toward the frontal lobes, each bed having been deposited in its present inclination on the growing edge of the delta, as the streams coursing over the embankment, already built up to water level by this process, came to the outer margin and let their load of sand come to rest by sliding down the frontal slope to the angle of repose for that material in water. (*See* pl. 7 and 8)

Plate 8

H. Ries. photo.

Section of glacial delta in eastern sand pit, Port Washington, showing fore-set and overlying top-set beds. View looking north

In the southern part of the sand plain exposed by excavation, the inclined, or fore set beds are not overlain by any distinct coating of horizontal, or top set beds but farther north such layers appear. (*See* pl. 8)

The bit of evidence here presented concerning the form of the ice front shows that the margin at this time was less regular than when it lay against or on the high moraine from 4 to 5 miles south. It evidently extended across Manhasset bay from the vicinity of Plum point to the opposite shore and thence westward lay against the land at least as far as College Point, where again there was built a small delta deposit later than the moraine. There is good reason, therefore, to believe that the water body in which the delta at Port Washington was built was cut off from the sound along the north shore of the island, and that the sound was as yet filled with glacial ice. Just north of Port Washington village, there is a deep channel or furrow beginning in the trough occupied by the middle one of three ponds and extending northeastward across the gravelly and till deposit to the vicinity of Mott point. The bottom of this trough, whose contours are shown on the topographic map, is about 75 feet above the present sealevel. The trough has the form of one of those creases eroded or kept open by water flowing out of the ice sheet or from one glacial lake to another along the ice front. At the time it may have connected the waters confined in Hempstead bay with the water held by the ice sheet in the Manhasset bay depression.

The crease at the southern end of Hempstead bay, at Roslyn, shows clearly that a stream once discharged there across the moraine on the plain, with its bed over 120 feet above the present sealevel. Hempstead harbor is bounded on the east quite up to the sound by land rising above 100 feet, so that, when the ice front retreated from the morainal wall at Roslyn, drainage would continue to escape through the Roslyn channel till the Mott point channel was opened by the retreat of the ice north of that point. At this stage any open water in Hempstead harbor would have escaped into the Port Washington body and its level fallen off to about 80 feet. This arrangement of cols and drainage channels, considered in relation to the retreat of the ice front, proved by the Port Washington stage,

makes it highly probable that for a time Hempstead harbor was the site of a small glacial lake, at first discharging at the 120 foot level at Roslyn, and later by the 80 foot channel into the Manhasset water body. It now remains to determine whether the high level of water in Manhasset bay was then at sealevel or whether it too was held up by a glacial barrier.

South of Manhasset is a col in the moraine, at an elevation of about 175 feet, much higher than many cols separating the bay from lower passes through the moraine in the country on the east of the bay. It is evident that this col, which lies just east of Lake Surprise, could not have been used as an outlet for the water confined in Manhasset bay after the ice front had retired as far north as Port Washington, for the water level had then fallen to 80 feet, as witnessed by the delta at that locality.

West of Manhasset bay, most of the region north of the moraine fails to attain the 100 foot level. The moraine itself presents a continuous barrier rising above the 80 foot contour line at all points till the vicinity of Maple Grove is reached. Between this locality and Prospect park in Brooklyn, there are eight or nine low, troughlike passes across the crest of the moraine, which might have served for the overflow of water held in on the north between the moraine and the retreating ice front as late as the Port Washington stage, while the ice, on account of its greater activity near the axis of the Hudson lobe, maintained its position close to the moraine in the vicinity of Brooklyn, at least depassing the 80 foot contour line on the back of the moraine so as effectually to prevent discharge by a lower level into New York bay north of the Narrows.

These troughs across the moraine are singularly uniform in level. In all those enumerated their bottoms lie according to the government survey between the 100 foot and the 80 foot contour lines. Some of them are clearly inosculating kettle-holes, marking the site of melting masses of the ice. From some of them, drainage creases can be traced out over the frontal plain. They are best developed in line with the bays and depressions on the north side of the moraine, and hence were probably the paths of subglacial streams, as in the case of the passes on the Oyster Bay quadrangle. They are however not unique in this portion of the moraine. There are

other similar passes at higher levels. Their coincidence of level is apparently accidental; but their repetition not only determined the level to which delta construction should reach in the temporary lake behind the moraine at this stage, but the fact also explains the failure to depart from that approximate level while the ice maintained its position. With the possibility of the water spilling over through several or all of these channels, the drainage, if the time were short, would hardly concentrate on any one of them. That the time was short, is shown by the small delta built at this level. Where the outpouring stream from the ice was strongest, the delta pushed out about a mile.

The deep drainage furrow dissecting the delta on a north and south line indicates a sudden falling off in the water level. This undoubtedly points to a change in the position or in the solidity of the ice barrier on the west, such as to permit the confined waters to escape into New York bay at a lower level than the passes in the moraine. The fact of such a change of level is indicated in a small delta at about 40 feet in the vicinity of College Point.

## College Point delta

A poorly developed delta fringes the southern slope of the bar of glacial drift which connects College Point with the village of Whitestone. The northern slope and much of the crest of this ridge are morainal, though sands are exposed here and there beneath this ice-laid coating. At a point about due south of the bottom of Powell cove, a section open in June 1900 showed the fore set and top set beds of a typical delta structure extending southward. The structure as in fig. 9 indicates a period of building at about 35 feet above the present sealevel, followed by a rise of the water level of about 5 feet, the whole indicating clearly a water body north of the main moraine at about 40 feet above the present sealevel.

The ice front had now evidently retreated along a part of the line somewhat north of its position at the Port Washington stage. That this retreat was not without slight advances, is probably indicated by the evidence of rising water level in the College Point delta; but the opening of crevasses in the ice margin and their sub-

sequent closing might under the local circumstances have accomplished, as in existing glaciers, such minor changes of water level.[1]

A glance at the topographic map will show that from Flushing bay, the shore line of which at the time the College Point delta was deposited must have been about 40 feet higher than now, there is a well defined channel extending westward from Newton through Winfield Junction to the head of Newtown creek. From this point escape of the water to or connection with the sea was possible either along the northwestward course of Newtown creek to the East river at Hunters point or, if that way was still blocked by the ice sheet, along a more southerly course between Williamsburg and Brooklyn into Wallabout bay, the highest land there lying between the 20 foot and 40 foot contours. From Wallabout bay a somewhat winding passage below the 40 foot level was open, permitting discharge into or connection with Gowanus bay just north of the moraine at the Narrows.

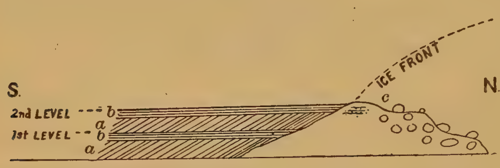


Fig. 9 Cross-section of the structures observed in the College Point delta. *a*, fore-set beds; *b*, top set beds; *c*, morainal ridge or bar

As for the possibility of the 40 foot delta at College Point having been deposited at sea-level, it should be stated that similar formations north of the moraine indicate widespread waters at about this level. When these have been fully investigated it may be necessary to admit a submergence to this extent. What is stated here must be taken with this reservation in mind.

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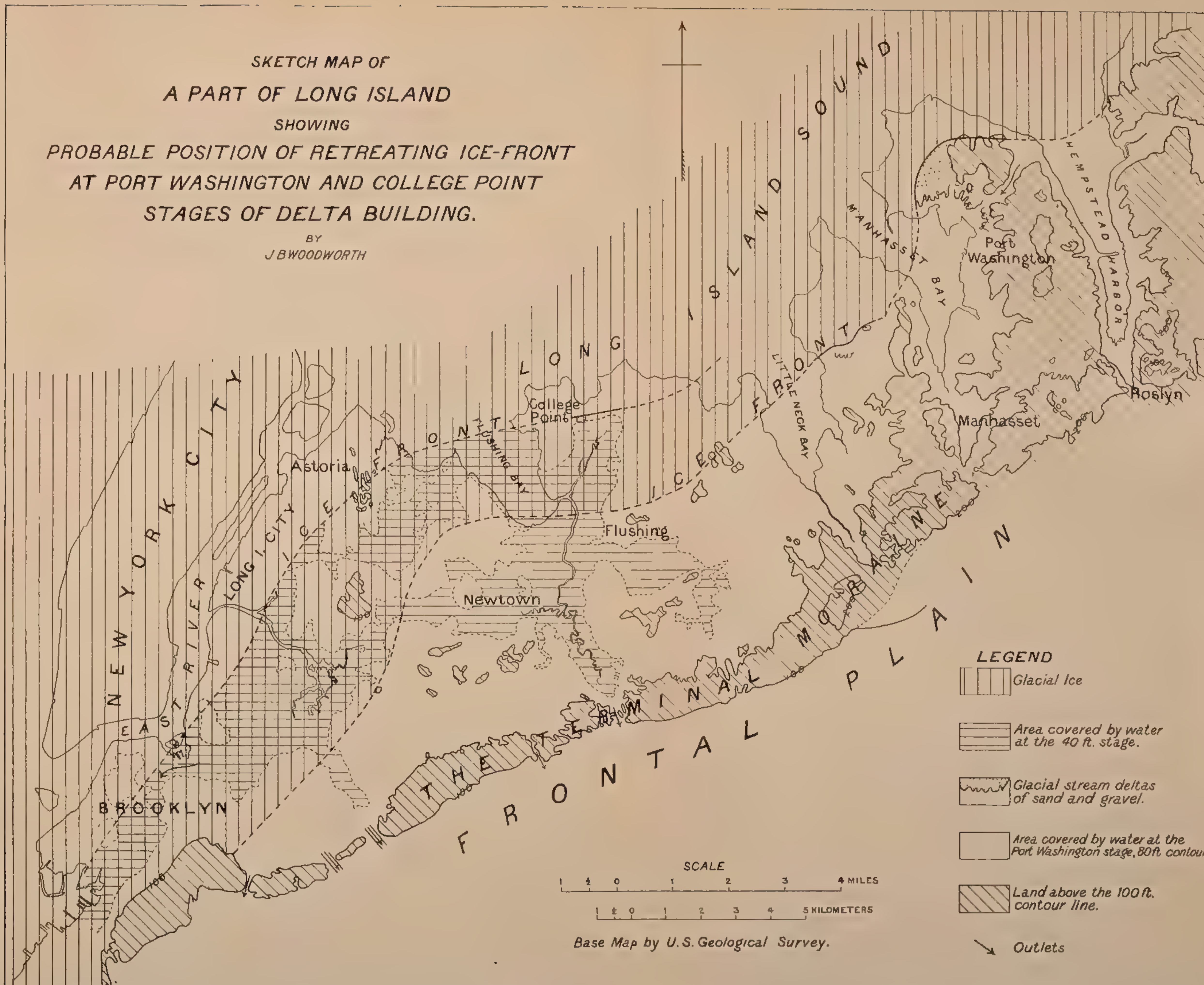
[1] *See*, on the formation of temporary lakes at the present time, Edouard Suess, La face de la terre. Paris, 1900. 2 : 590–97, and the authors there cited; also De Lapparent, Traité de géologie. 4me ed. Paris, 1900. p. 302–3, on the sudden drainage of glacial lakes. For American glacial lakes of the class here described, *see* H. B. Kümmell, Lake Passaic, an extinct glacial lake, in N. J. geol. sur. an. rep't for 1893. Trenton 1894. p. 225–328; separately printed 1895. p. 1–89; Crosby and Grabau, Glacial lake deposits near Boston, Science. 1896. 3 : 212–13; also Grabau in Crosby's Geology of the Boston basin. 1900. v. 1, pt 3, p. 564–600, pl. 25; and Warren Upham, The glacial lake Agassiz, U. S. geol. sur. Monograph 25. 1895. 658 p.

The position of the ice front is definitely fixed in this field during the retreat by certain sandy deltas backed by morainal deposits. Elsewhere in the retreat from the main moraine, the position of the ice front is indefinite. In the hypothesis of glacial lakes held in by it, it is placed at certain points so as to control the outlet of water bodies or lakes whose level is known. There are in this district certain drift ridges which simulate the form and extension of the main moraine, and they appear to have developed in part during the retreat from the outer ridge at East New York. Their trend and position accord as nearly as might be expected with the position of the ice front at the time of the Port Washington and College Point stages.

In a broad sense most of the western part of the island north of the moraine is morainal. But it has a distinct aggregation in belts rudely parallel to the outer moraine and presumably to the ice front as it retreated. Some of the thicker deposits may be due to the working over of the moraine whose disappearance beneath this later drift at Roslyn has been noted.

A glance at the contours on the map will show a line of irregular, flattish drift hills with hollows lying about 2 miles north of the main moraine. This line is encountered at East Williamsburg. On the north and west of Corona is a curved line of deposits highly suggestive of an ice margin, and the phenomena are repeated in deposits bending around from East Calvary cemetery near Hunters northeastward past Ravenswood into Astoria and thence to the East river near Sanford point. This line is, again, about 2 miles farther back than the Corona line, and the two bend southwestward toward New York bay, as the line might be expected to bend if the ice were not completely stagnant along the axis of most rapid movement down the Hudson valley. Moreover, the Astoria line is apparently a continuation of the College Point frontal deposits, and they are so represented by the line drawn on the accompanying sketch map (pl. 9). The line of the Port Washington stage is not so definitely known. From Littleneck bay it is represented as following the Corona deposits; it may have rested against the drift hills on either side of the southern end of Flushing bay; the results are practically the same in either view.




The map includes the area from Roslyn and Glen Cove on the east to Brooklyn and from the moraine to the north shore. The obliquely ruled black lined areas comprise land above the 100 foot line. The unruled area between the moraine and the heavy black line representing the Port Washington ice front gives the approximate extent of the fresh-water lake held in at the Port Washington stage. The dotted surface with lobate margins shows the position of the delta of that stage, and the arrow indicates the channel through which the Hempstead bay lake drained into Manhasset bay lake, from which in turn the water may have escaped into the Little Neck and Flushing bay region, and so spilled over the moraine in some one or more of the low passes marked by small arrows.

## SUMMARY OF GLACIAL HISTORY

From what has been stated of this district, it appears that relatively early in the Glacial period the area now forming the western part of Long Island received a thick coating of gravels and sands, some of the debris being eroded from the deposits of the coast plain remaining in the area, some of them being borne from the mainland on the north; that probably somewhere near the middle of this time, as indicated by the occurrence of the deposits in the section, there was an actual invasion of the district by ice, either floating ice or land ice, in either case probably the margin or detached floating portions of the front of an ice sheet laying down till in the district. These deposits as a whole underlie the moraines and are apparently the Columbia formation of McGee. Certain aspects of the deposits seem to be paralleled in New Jersey by the yellow gravel formations described by Salisbury.[1] Subsequent to their deposition, which locally affords no decisive evidence of the relation of land to sealevel, they appear to have been somewhat dissected by open air streams, indicating an epoch of deglaciation or ice retreat of indefinite duration. Following this came the deposition of two lines of moraines in the area, an outer and inner or earlier and later, but in the western part of the field the later ice front depassed the position of the earlier advance. The land appears to have been as high above sealevel as it is now, if not higher; and during the retreat of the ice one or more temporary lakes existed back of the moraine, first at 80 feet above the present sealevel, then possibly at about 40 feet. This lower body of water may have been at sealevel as stated above. With the retreat of the ice front across East river, the region escaped from the field of glacial action, and its latest glacial deposits and features pertain to the very beginnings of the ice retreat, a time but slightly past the culminating phase of the last or Wisconsin glacial epoch. Of any such distinctions as a Champlain and Terrace epoch there appears here no trace, for the overwash plain was making while the ice was at its maximum extension, and the glacial terraces marked by the small deltas described in this

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[1] Salisbury, R. D. N. J. geol. sur. An. rep't state geol. 1895. p. 67–72.

report were made before the ice had melted back 5 miles from its extreme prolongation. They clearly belong however to the period of retreat; but the mainland on the north was still actively glaciated.

## POST-GLACIAL CHANGES AND PROCESSES NOW IN ACTION

The disappearance of the ice from a glaciated district of itself induces certain changes which are not wanting in this part of Long Island. The melting out of remnants of the glacier or those parts of its base which filled depressions has in many instances given rise to small lakes and tarns. A number of these small lakes exist in the moraine west of Roslyn. Of these, Lake Surprise is the best and largest example. It lies at an elevation of about 200 feet above the sea in a basin whose sides are gravelly till. Presumably the bottom is clay rather than gravel, as the waters would escape through the latter. Such lakelets depend on the percolation of the ground waters through the relatively gravelly or sandy materials of the superficial deposits, the water standing in the pond at the level of the ground water in the gravels. Other small lakelets lie in depressions in the outwash plain, as at Plattsdale. Westbury pond is one of this class named on the map.

The streams of the plain flow, as has been indicated, in courses which were carved out by the once more vigorous glacial streams or in still older channels on the north side of the moraine. Owing to the porosity of the glacial gravels, much of the rainfall soaks into the ground and issues near sealevel in the form of springs, hence, since the run-off is small, little erosive work has been accomplished in the post-glacial epoch. Yet the streams which converge into Oyster bay have contributed enough gravel and sand to form a narrow flat, modified by wave action where the village of that name stands.[1]

Marine action at the present sealevel has cut back the outwash plain on the south coast as well as the Far Rockaway ridge, so that the outermost extent of both of these formations is now destroyed,

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[1] In June 1900 a well bored by means of a drill on the north side of Main st. 760 feet distant from the beach met at the depth of 45 feet (35 feet below sealevel) a marl containing oyster shells (*Ostrea* sp). Above this bed were gravels, below light yellowish sand.

and a low bluff faces the sea. Bars of sand have been partially or wholly thrown across the old glacial stream channels by the waves. The most notable of these marine deposits are in the form of offshore bars, subject to frequent changes in hight and position.[1]

On the north shore, where the wave action is less vigorous, there has been less cutting back, but, the cliffs being higher, other factors, such as landslips and the ordinary work of gravity on loose materials, nearly compensate for this difference in the quantity of materials handled by the waves. The wave action on this side of the island has been in part resisted by the numerous boulders which come to rest upon the beaches from the undercutting of the till, a feature which is wanting on the south shore. Numerous small barrier beaches occur, usually with outlets at their western end for the lagoons or back bays which they inclose. A few small masses of land, which otherwise would stand out as islands along the north shore, are tied together and so to the main island by these beaches, as in the case of Center island in Oyster Bay harbor, which is thus joined with Oak neck, and that in turn to the land. The upper and inner portions of these beaches are composed of dune sand.

In the narrower bays and creeks behind the barrier beaches marine marshes have developed on both sides of the island. The extent of these deposits on the south side is very much less than on the south coast. The land in such situations usually slopes beneath the inner margin of the marsh flats without evidence of former wave action at this level. Both the beaches and the marshes have developed in post-glacial time. If during all this time the sea stood at its present level, before the barrier beaches were formed the waves must have had a relatively free run against the sides of certain inclosed uncut bay shores of the present time, and would have nipped the incoherent materials so as to form a small but perceptible cut bench and bluff. The absence of this feature in what but for the barrier beaches would be exposed bay shores seems explicable only on the hypothesis that the land has sunk, so that the wave-cut terraces,

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[1] For a recent discussion of the origin and terminology of seashore deposits, consult F. P. Gulliver, Shore line topography. Am. acad. arts and sci. Proc. 1899. 34:151–258; also F. J. H. Merrill, Barrier beaches of the Atlantic coast, Pop. sci. mo. 1890. 37:736–45.

made when there were no barrier beaches, are beneath the present sealevel.[1]

Wherever the breadth of water is sufficient, however, and the depth too great to permit of marsh growth the bay shores are now being cut back in a marked manner by wave action, as at Cooper bluff.

Evidence of local depression of the shore line is found in beds of peat extending outside of the beach below low tide level. Such a bed, containing a flattened log, was exposed in the summer of 1900 at the northeast end of the barrier beach uniting Prospect point with Sands point. Peat was also exposed on the front of the beach at low tide half a mile southeast from Prospect point. In view, however, of the compressibility of the original swamp deposits, these localities can hardly be regarded as proofs of a general sinking of the island.[2]

It is questionable whether even measurable evidence of a slight depression of the shore line along a coast of incoherent and yielding materials such as the clays and gravels of the north coast of Long Island may be taken as evidence of a movement of the continent. There is a slow movement of the loose materials toward the shore in many high bluffs. At Ragged Land point east of Northport harbor this movement in clays has developed a landslide structure, a process which presumably has been continuous since the suggestive name was given to the irregular projection which these clays make on the beach. They move with something like glacial flow, overrunning the normal beach, the wave action being there unequal to the task of maintaining a straight shore line.

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[1] De la Beche appears to have first made this point in the case of certain British beaches. *See* Geological manual. Phil. 1832. p. 73–75.

[2] Suess, Edouard. La face de la terre. Paris 1900. 2 : 670–89.

## BIBLIOGRAPHY

**Mather, W. W.** Geology of New York; 1st geological district. 1843. 1: 165–77, 246–78.

**Lewis, Elias, jr.** Ups and downs of the Long Island coast. Pop. sci. mo. 1877. 10 : 434–46.

—— On water courses upon Long Island. Am. jour. sci. 1877. 13 : 142–46.

—— Certain features of the valleys or water courses of southern Long Island. Am. jour. sci. 1877. 13 : 215–16, 235–56.

**Upham, Warren.** Geology of New Hampshire. 1878. 3 : 200–5.

—— Terminal moraines of the North American ice sheet. Am. jour. sci. 1879. 18 : 81–92, 197–209.

**Chamberlin, T. C.** Preliminary paper on the terminal moraine of the second glacial epoch. U. S. geol. sur. 3d an. rep't. 1883. p. 377–81.

**Merrill, F. J. H.** Geology of Long Island. N. Y. acad. sci. Annals. 1886. 3 : 341–64.

—— On some dynamic effects of the ice sheet. Am. ass'n adv. sci. Proc. 1886. 35 : 228–29.

**Hollick, Arthur.** Some further notes on the geology of Long Island. N. Y. acad. sci. Trans. 13 : 122–32.

—— Dislocations in certain portions of the Atlantic plain strata and their probable causes. N. Y. acad. sci. Trans. 1894. 14 : 8–20.

**Crosby, W. O.** Outline of the geology of Long Island in its relations to the public water supply. Technology quar. Bost. 1900. 13 : 100–19.

**Shattuck, George B.** The Pleistocene problem of the North Atlantic coastal plain. Johns Hopkins university circular 152. May 1901. Reprint p. 17.

## GLOSSARY

**Terms used in this bulletin or found in writings concerning glacial phenomena**

Aggradation, aggrading. Deposition of alluvial plains by streams

Borrow-pit. Pit from which gravel or sand is taken in construction work

Boulder belt. Extended pile of boulders accumulated in the form of a frontal moraine; or excessively bouldery ground marking the former position of the front of an ice sheet

Boulder train. Term applied in the United States to the train of boulders and pebbles distributed by the ice sheet over the country southward of some readily identified rock having a limited exposure in the glaciated field and of which the boulders and pebbles consist

Col. That part of a divide which lies in a pass

Columbia formation. Series of loams, gravels, and sands occurring in the coastal plain, forming terraces and river deltas deposited during the submergence of the land before the last or Wisconsin glacial epoch and after the tertiary. The deposits are variously subdivided in New Jersey and Maryland. The coarseness of some of the deposits indicates a period of cold with signs of glaciation and one or more advances of the ice over the glaciated district

Cone. Conical pile of rudely stratified sand and gravel often with included boulders with a fan-shaped outward base, and a steep face toward the position formerly held by the ice front against which it was deposited by outpouring, waste-laden water from the melting ice

Crease. One of the channels formerly held by a stream coursing over the surface of a delta or glacial sand plain and now usually dry for the reason that the water came from the melting ice along the front of which the deposit was built

Cuesta. In physical geography, a land form consisting of a perceptibly inclined plain overlooking a steep slope or escarpment on its higher side, developed by erosion on the retreating outcrop edge of a gently inclined hard stratum

Digitation. Fingerlike branching of the headwater tributaries of streams

Drift. *See* Glacial drift

Drumlin. Lenticular or oval, drum-shaped hill composed of till deposited by an ice sheet; distinguished from a kame by its usually greater size, its elongate oval form, and its composition

Drumlinoid. Having the form of a drumlin

Esker. Long winding ridge of gravel and sand, often associated with glacial sand plains and kames, and considered by most geologists to be the deposit made in the channel of a subglacial stream

Esker-fan. Small glacial sand plain or delta with a lobate outward margin and a terrace, often cuspate, on the inward margin facing the ice sheet against which it was formed at the same time that the associated esker was being deposited inside the ice sheet

Fore-set beds. Cross bedding often on a large scale developed in formation of the subaqueous portion of deltas. Each fore-set bed is an underwater talus formed at the growing edge of the delta where the stream coursing over the surface of the delta drops its load on reaching open water. The beds incline steeply forward in the direction in which the delta is building, hence the name. Fore-set beds are usually overlain by the top-set beds, which see

Fosse. Depression or unfilled area often found between the terraced ice contact of glacial sand plains and morainal mounds forming a belt within the ice covered field, as on Nantucket

Glacial drift. In a general sense, the boulders, till, gravels, sands and clays transported by glaciers or the stream flowing from them; specifically in some writings, unstratified or ice-laid drift. Unmodified, unstratified, or unassorted drift are expressions referring to the till or ice-laid drift; modified, stratified, or assorted drift are expressions applied to the water-laid gravels, sands, and clays produced in the vicinity of melting glaciers or remnant masses of ice

Glacial lobe. One of the lobate protrusions of the margin of an ice sheet, sometimes a score or more miles in width as where the ice has been free to spread out in depressions along its margin

Glacial retreat. A glacier is said to retreat when its front recedes. The ice may be actually moving forward toward this front, but the rate of backward melting at the front, if it exceeds the rate of forward movement, will cause the position of the front to recede

Glacial sand plains. Deposits of stratified gravel and sand in the form of deltas and gently sloping fans, deposited by streams along the margin of a glacier. Where built into open water, the deltas usually show fore-set beds in the body of the deposit and top-set beds capping the whole. Where the deposit has banked up about the margin of the ice front, a terrace is formed by the subsequent melting out of the ice

Glaciated. Said of a country which has been scoured and worn down by glacial action, or strewn with ice-laid drift

Ground moraine. Coating of boulders or mixture of boulders, gravel, sand, and clay which a glacier leaves on the surface of a country. In existing glaciers, the debris carried along under the ice

Ice contact. Terracelike slope at the iceward margin of deposits which have been banked up against the ice front or about masses of ice. The slope is often cast in mounds (kames) and hollows which result from the melting out of buried masses of ice. Where smooth and even like a river terrace, it may be distinguished from a river terrace by its position often being such that a river could not have flowed along its base

Ice-laid. Said of boulders, or mixtures of boulders, gravel, sand, and clay which have accumulated under a moving glacier or have come to rest on the ground from the melting out of the ice in which the material was embedded

Ice sheet. Form of glacier moving radially outward from a region of great snowfall and covering usually all but the highest mountains in its path

Interglacial. Interval between two glacial epochs or advances of the ice

Intraglacial. Said of phenomena peculiar to the field actually covered by the ice at any given time; contrasted with extraglacial

Interlobate. Lying between two lobes of a glacier

Kames. Mounds of stratified or rudely stratified gravel and sand often separated by hollows; due to the irregular settling or deposition of deposits laid down in the presence of melting masses of ice

Kame moraine. Belt of glacial deposits laid down by the interaction of ice and water at or just within the margin of an ice sheet, and having the form of kames.

Kamy. Characterized by low knobs and shallow depressions (colloquialism)

Kettle-hole, ice-block hole. Pit or depression sometimes occupied by standing water; often found in glacial sand plains or other glacial deposits where masses of ice have melted out

Lobe. One of the rounded spurs of the outward margin of a delta formed where a stream has pushed its deposit out beyond the general line; also one of the protrusions of ice along the margin of a glacier

Moraine. Swiss term for the debris transported and deposited by glaciers; in America, the ice-laid drift accumulated about the edge of a glacier, usually in belts and often a mile or more in width, classified with regard to position in relation to the ice as frontal, submarginal, lobate, interlobate, etc.

Osar. Swedish term for eskers; Swedish singular os, plural ösar; through misunderstanding, English singular osar, plural osars have been used

Outwash. Said of plains of gravel and sand transported by glacial streams and deposited along the ice front

Overwash. Said of plains of sands and gravels or terraces supposed to have been moraines leveled off by glacial streams along an ice front

Parma. Geologic term used by Suess for a fold in strata lying in advance of the main area of folds in a system of folded rocks

Piedmont. Lying at the base of the mountain; specifically on the Atlantic slope of North America, the belt of ancient rocks of little or moderate relief lying between the coastal plain and the belt of mountainous relief farther inland

Post. Prefixed to the name of a geologic period or epoch to denote any subsequent time

Post-glacial. Time since the disappearance of the great ice sheets of the Pleistocene period; in some writings, the time immediately following the last glacial epoch

Pre. Prefixed to the name of a geologic period or epoch to denote any or all previous geologic time; in a narrow sense, the immediately preceding time or rocks peculiar to that time; as in

Pre-glacial. Term generally intended to refer to phenomena immediately preceding the glacial period; often vaguely used, and in older writings often applied to formations now understood to be of Pleistocene age but older than the last or Wisconsin epoch

Quadrangle. In references to the topographic map of the United States, one of the four-cornered divisions of land corresponding to an atlas sheet; the area mapped as distinguished from the map or atlas sheet

Retreat. *See* Glacial retreat

Roche moutonnée. One of the half rounded smoothed knobs of rock produced by glacial erosion

Run-off. That part of the rainfall which discharges into the streams of a region without passing underground

Sand plain. *See* Glacial sand plains

Striation. Act of scratching the surfaces of ledges and boulders by the movement of glaciers

Striae. Scratches or furrows produced on rock surfaces by glacial action

Tarn. Small lake, as in the glaciated district of Scotland; specifically, a mountain lakelet of glacial origin, a rock basin

Terminal moraine. In North America, the outermost line of moraine made in the last or Wisconsin ice epoch traceable from Nantucket across Marthas Vineyard, Block Island, Long Island, and thence westward over the mainland

Terrane. Any definite portion of the earth's crust defined by its geographic position or its geologic age; as the piedmont terrane, the pre-Pleistocene terrane

Thalweg. Stream channel at the bottom of a valley

Till. In the widest sense, rock debris carried and deposited by the direct action of a glacier; typically, a more or less compact mass of boulders, gravel, with sand or clay, without stratification and necessarily of glacial origin

Top-set beds. Horizontal or gently inclined layers of gravel and sand which form the superficial coating of glacial sand plains or deltas; made by wandering aggrading streams usually at or above the level of the sea or lake in which the delta is building

Water-laid. Said of detritus deposited by water

Wisconsin epoch. Term employed in this report for East Wisconsin, the name proposed by Prof. Chamberlin for the last glacial epoch in the state named; believed to include the time of formation of the later glacial drift in the eastern United States from the terminal moraine northward into Canada

# INDEX

The superior figures tell the exact place on the page in ninths; e. g. $648^3$ means page 648, beginning in the third ninth of the page, i. e. about one third of the way down.

(*Pages 671–672 were bulletin cover pages*)

# GENERAL INDEX

r prefixed to page numbers refers to the director's report in v. 1; other page numbers refer to the appendixes. The superior figures tell the exact place on the page in ninths; e. g. 8$^{3}$ means page 8, beginning in the third ninth of the page, i. e. about one third of the way down.



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*For full indexes to museum bulletins,* see *index printed with each bulletin.*

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*For full indexes to museum bulletins,* see *index printed with each bulletin.*

Map of the Pleistocene geology of the Oyster Bay and Hempstead quadrangles on Long Island


LEGEND

RECENT
AND NOW FORMING

Marine alluvium; beaches of gravel and sand

Eolian deposits; dunes and blown sands

PLEISTOCENE

WISCONSIN EPOCH OR LAST GLACIAL

Glacial sand-plains, Port Washington stage. Sand and gravel

Morainal deposits of Port Washington stage over older glacial deposits

Veneer of till and erratic blocks north of the inner moraine

Moraine of the Harborhill stage; gravels at Harborhill; typical till in other places

Kame-moraine areas with scattered boulders marking outer moraine

The outwash plain of gravel and sand

OLDER PLEISTOCENE

Manhasset gravels and sands under T.

The Manhasset boulder bed; a local glacial deposit in the Manhasset sands

PRE-PLEISTOCENE

Far Rockaway gravels, yellow gravels

Cretaceous clays and sands in disturbed positions

Gravel and Sand pits

Clay pits

Kaolin pits

Topography by U. S. Geological Survey in cooperation with the N. Y. State Engineer and Surveyor

Scale 1/62500

Contour interval 20 feet.
Datum is mean sea level

Pleistocene Geology by J. B. Woodworth. Surveyed in 1900